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THE TIN DEPOSITS OF THE MALAY PENINSULA WITH SPECIAL REFERENCE TO THOSE OF THE KINTA DISTRICT.

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Geographic position of the Malay tin regions.—The Malay Peninsula is the southeastern extremity of the continent of Asia. It extends from about latitude 14° N. in a southerly and southeastern direction to about latitude 1°°20′ N., and still farther south a chain of islands connects it with the main part of the Australasian archipelago. It is a narrow strip of land about 900 miles in length and from less than 50 miles to over 150 miles in width.

The northern and central parts of the peninsula belong to Siam, though the British possessions of Burma include some of the northwestern part. The southern part of the peninsula is comprised mostly in the native states of Perak, Pahang, Selangor, Negri Sembilan, and Johor, ruled by independent sultans, but

FIG. 1.—Map of lower part of Malay peninsula showing Federated Malay States.

more or less under British influence. These principalities have recently combined under the name of the Federated Malay States. Along the lower coast of the peninsula the British own certain small strips of land and islands, including Province Wellesley, Dindings, and the Malacca Territory on the mainland, and the islands of Penang, Pangkor, and Singapore. These, together with several other islands, represent what are known as the Strait Settlements. The Federated Malay States at present comprise most of the tin regions worked on the peninsula.

The tin deposits occur in greater or less quantities from the state of Johor in the southern extremity of the peninsula, northward to the limit of the state of Perak on the Siamese border, a distance of some 350 miles. To the north of this limit in Siam, even beyond the high peak of Mount Kedah, tin has been reported, but the deposits have not been much explored, and no very prominent mines have been opened. This may possibly be due to the unexplored character of the Siamese part of the peninsula, as the roads are not so good as in the Federated Malay States, and travel and exploration are very difficult in the dense jungle. Even in the Malay states, though the tin is found over a large area, most of the production comes from a few places. By far the larger part of it is mined in the states of Perak and Selangor, while very little has been found in Johor, and the production of Pahang and Negri Sembilan is small.

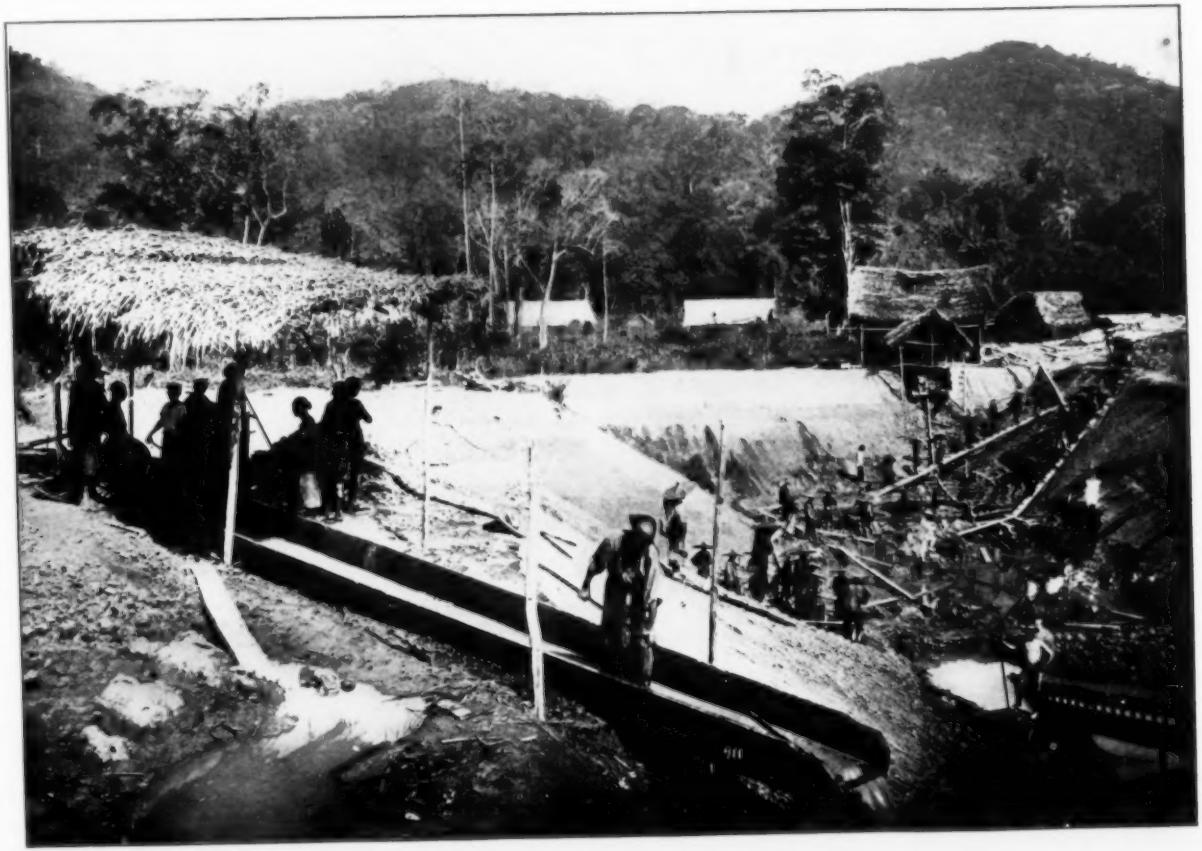
Perak is the largest producer of the Malay states, supplying considerably over half of the tin of the peninsula, and the Kinta district is at present the most important tin locality in that state, though tin is also mined at Thaiping and other places. In Selangor the most important mining center is Kwala Lumpur, and the production of this region is second only to that of the Kinta district. Besides the places already mentioned, many other smaller tin districts exist, and, in fact, most all of the numerous small native towns on the west slope of the peninsula are largely dependent on the tin industry.

Most of the tin regions are on the western side of the mountains which form the backbone of the peninsula. On the eastern side very little tin is found. On the other hand, a considerable

amount of gold occurs on the eastern side, while very little has been found on the western side. Hence the eastern slope is known as the "gold region" and the western slope as the "tin region."

To the southeast of the peninsula, tin is mined on the islands of Banka and Billiton, which are owned by the Dutch. In Banka the mines are worked by the government and are more productive than those of Billiton, which are operated by an independent company. The occurrence of the tin on these islands is said to be similar to that on the peninsula. Tin is found also on the island of Sumatra, off the southwest coast of the Malay peninsula, but has not been worked to any great extent. Its occurrence is said to be somewhat like that of the peninsula, and the fact that the production is small is said to be due to the unexplored character of the country and to the constant troubles between the Dutch authorities and the natives.

General geology of the Malay tin regions.—The Malay peninsula consists of a central axis of rugged mountains, with occasional subordinate parallel or diverging axes and isolated peaks. The whole region is covered by a jungle of tropical vegetation so dense that the roads and trails have to be hewn through it with an ax. In the tin regions the main range is composed of granitic rocks, occasionally intersected by feldspathic and other dikes, while in places are found gneissic and schistose rocks, with occasional areas of a white, highly crystalline limestone. The granite is mostly of a gray color and is composed of quartz, feldspar, and biotite or hornblende, or both. There seem to be all gradations from a granite with biotite and no hornblende to a granite with hornblende and no biotite. Black tourmaline is a common constituent of the granite in the neighborhood of the tin deposits. The limestone is generally a highly crystalline marble of a white color, occasionally streaked or spotted with gray. No fossils were seen in it, and it is said that none have been found. Such as may have existed seem to have been destroyed by the metamorphosis of the rock, though a more thorough search might reveal traces of them. The limestone is especially abundant in the Kinta district, though also found



Mining and washing tin ore near Ipoh, Perak, Malay peninsula.

elsewhere on the peninsula. Occasionally strata of a fine-grained, friable sandstone occur on the lower slopes of the mountains, which appear to be younger than any of the other rocks mentioned. The granitic rocks and limestone, however, are the formations most commonly seen in the few places where any rocks appear through the soil.

All the rocks, especially those of a granitic nature, are much

FIG. 2.—Tin diggings in the alluvium at foot of granitic hills, Kinta district, Perak, Malay peninsula.

decayed, often to a depth of many feet, and the detritus from them has formed large areas of alluvium in the mountain valleys and along the lowlands on the coast. Much of this alluvium contains more or less oxide of tin or cassiterite in particles and fragments of varying size, forming what might be termed "tin placers," and it is from these deposits that the mass of the tin of the Malay peninsula is derived. Tin also occurs in the granitic rocks and limestone, as will be more fully described farther on, but though these rocks were doubtless the source of the alluvial tin, yet the ore in them is at present worked to only a very small extent.

Location of the Kinta district.—The tin region most carefully examined by the writer was the Kinta district in Perak, and this will therefore be described more in detail than the other districts mentioned. The Kinta district has no definite boundaries, but the name is a general term applied to an area in the southern part of the state of Perak, in the valley of the Kinta river. This stream is a branch of the Perak river which flows through the state of the same name into the Strait of Malacca below Teluk Anson. The Kinta district comprises a more or less inclosed valley about 40 miles in length in a north-and-south direction, about 30 miles in width at its south end, and about 5 miles at its north end. To the east is the high granitic range, forming the backbone of the peninsula and rising in some places about 8,000 feet above the sea ; to the west is a lower granitic range, rising some 3,000 feet and separating the valley from the Strait of Malacca. Between these ranges are lower mountains and areas of limestone, surrounded and partly covered with great tracts of alluvium. Twenty years ago the Kinta district was almost unknown, and Thaiping and Kwala Lumpur were the great tin centers, but now it is the most important district on the peninsula. It is intersected from north to south by a railway which is being extended at both ends. Among some of the more important mining centers in the district are Campar, Gopeng, Batu Gajah, Tronoh, Cacha, Lalang, Papan, Lahat, Chongkat Pari, and Ipoh, the last being the commercial center of the district; in fact, the alluvium over large areas has been completely stripped from the bed-rock in search of tin, and has been overturned in great piles, leaving the once fertile soil in a condition of desolation similar to the old gold placer diggings in parts of California.

Mode of occurrence of the alluvial tin in the Kinta district.—Most of the tin ore of the Kinta district is derived from alluvial deposits varying in character according to the nature of the rocks from which they have been derived and the distance to which they have been transported. In the larger valleys where the detritus from areas of different rocks has been mixed, the alluvium is commonly composed of a heterogeneous mass of

Tin mine of Mr. Foo Choo Choon, Tronoh, Perak, Malay peninsula.

white, gray, or red sandy or gravelly clay, often of a mottled character, containing numerous small quartz fragments about the size of a pea, derived probably from the decay of granite and in part from quartz veins, together with pebbles and bowlders of granite, gneiss, schist, pegmatite, limestone, etc. The alluvium in the hills, however, nearer its source, varies more in character, distinctly reflecting, in different places, the nature of the different rocks from which it has been derived. Frequently the alluvium is much stained with iron, and carries layers and masses of rusty ferruginous material consisting partly of sand cemented by iron, and partly of masses of granite and quartz with iron pyrites rapidly oxidizing and forming a brown mass. Sometimes the alluvium contains large quantities of vegetable remains and partly lignitized wood.

The dense tropical vegetation has given rise to large quantities of organic acids in the soil, and these have often leached the iron from the tin alluvium, leaving a clear white or gray mass, while in other places not so much exposed to this influence the gravel is still discolored. This is especially true of the upper parts of the deposits, which have often become entirely bleached, while the deeper parts are still heavily impregnated with iron. The waters in most of the mines are heavily charged with iron, which is deposited on the sides of the pits and shafts, showing that chemical action is still very active.

The tin occurs in the alluvium in different ways. Sometimes it is scattered through it from top to bottom in comparatively uniform quantities; sometimes it is in layers of rich ore separated by layers of lean or barren ground; sometimes it is richest on the bed-rock, and at other times higher up in the deposit. As a general rule, however, there is a covering, or "overburden" as it is called, of barren alluvium from 10 to 40 feet or more in thickness, and the tin ground is found beneath this. The best alluvium occurs immediately at the foot of the mountains. Higher up it is often richer, but of small extent, while farther away it is thicker, but of lower grade. The ordinary tin-bearing strata vary from 1 to 30 feet in thickness, though sometimes they reach over 100 feet. At Gopeng, the Gopeng Tin Mining

Co., an English corporation, works alluvium which carries tin from the surface down to a depth of from 5 to 30 feet without any barren "overburden". At Campar, a French company, known as La société d' étan de Perak, has large open pits in the alluvium of the valley of the Campar river, where the tin-bearing stratum varies from 2 to 10 feet in thickness and is overlaid by a

FIG. 3.—Stripping new tin ground south of Campar, Perak, Malay peninsula.

barren "overburden" of about 40 feet in thickness. At Tronoh, in the well-known mine formerly owned by Mr. Foo Choo Choon, but recently sold to an English company, the "overburden" is from 30 to almost 40 feet in thickness, and the tin-bearing ground below has been penetrated by an open pit and an inclined shaft. The incline is about 400 feet long, equal to about 140 feet vertically, and the bottom of the tin ground has not yet been reached. This thickness of tin-bearing alluvium is, however, very exceptional. Many other cases, showing other variations in the conditions of the tin-bearing alluvium, might be cited.

At the bottom of the alluvium is generally either granite or limestone, though frequently where the tin stops, barren alluvium or rock decayed *in situ* separates it from the bed-rock, so that the solid granite or limestone is not always seen. This is especially true in granitic areas where the surface of the rock below the alluvium is often altered to a soft, partly kaolinized mass. Sometimes beds of coarse granite pebbles and bowlders, forming the substratum of the tin alluvium, have decayed *in situ* in the same manner as the surface of the original rock; and it is not uncommon to see rounded granitic fragments converted into a soft putty-like mass, which when broken up gives rise to angular particles of the original quartz of the rock and a soft clay resulting from the decay of the feldspar. Hence angular quartz may often be found in deposits that have been transported long distances. Such an occurrence is seen on the property of the Gopeng Tin Mining Co., where the tin-bearing stratum consists of a more or less ferruginous deposit of sandy and gravelly material occupying a ridge on the side of a small stream and underlaid by a pebbly stratum like that just described. In the creek bed below, near the native town of Gopeng, tin alluvium washed down from the ridges is extensively worked by the Chinese.

The limestone bed-rock is often leached in deep hollows and caves, as seen at Chongkat Pari and near Tronoh (see Figs. 4 and 6), while elsewhere, as seen between Ipoh and Lahat, it forms an undulating surface with alternating protrusions and recessions, following regular lines, probably influenced by lines of bedding, and resulting in a series of natural riffles behind which cassiterite has concentrated. (See Plate IV.) This occurrence is similar to the way gold has collected behind limestone riffles near Columbia, in California, and the country has been stripped in search of ore in much the same way as in the California region. The road from Ipoh to Lahat runs through a broad valley, and the rough surface of the bare limestone bed-rock is seen in many of the old workings.

Tin alluvium frequently occurs on ridges and hills as well as at lower levels in the valleys and creek beds. This sometimes suggests strongly that, since the formation of tin alluvium began,

there has been an elevation of the region followed by subsequent erosion, with the result that the older tin alluvium occupies the higher places, while the younger alluvium, derived probably in part from the older deposits, occupies lower levels, in much the same way as the Tertiary gold placers of California often occupy the higher spots and the more recent placers are found in the present stream beds. This may be true in some of the tin deposits, but it is necessary to distinguish between such occurrences and the cases where the tin deposits on the higher places are simply residual deposits formed *in situ* by the superficial decay of tin-bearing rocks, without removal of the tin from the region of its source.

Nature of the tin ore in the Kinta district.—The tin occurs in the form of cassiterite or oxide of tin (SnO_2), often well crystallized in tetragonal prisms with fine terminations, though the fragments in the alluvium have been more or less rounded by attrition. The ore varies in color from black or brown to gray, grayish-green, white, or transparent, but the commonest kind is of a dark brown or almost black color with a resinous luster. In the mountains, near its source, the ore is angular and in comparatively large fragments, sometimes from an inch to a foot or more in diameter, but this is rare, and farther down hill it becomes more and more rounded and fine-grained, the common alluvial tin fragments ranging from the size of peas to that of sand grains or smaller. In fact, efforts are now being made to work tin ore that exists as a fine powder in the mud banks that line certain parts of the west coast of the peninsula.

The amount of tin in the ore as commercially mined ranges from 69 to 73 per cent., an average of about 70 per cent. being considered very fair. The theoretical amount of tin in cassiterite is 78.6 per cent. The richness of the tin ground varies much in different places. The average value of the alluvium worked in the Kinta district is probably about 1 per cent. of cassiterite, and ground of this grade pays well to work, if favorably situated. If the alluvium contains 2 per cent. of cassiterite, it is considered exceptionally good ground, and with 3 or 4 per cent. it is considered remarkably rich. Sometimes thin strata in the alluvium

are very rich in cassiterite, containing from 40 to 60 per cent., but this is very rare.

Minerals associated with the tin ore in the Kinta district.—With the tin in the alluvium are associated much tourmaline, hornblende, wolframite, and magnetite, while in smaller quantities are found white mica, topaz, scheelite, and sapphire, and it is said that in parts of the peninsula small quantities of thorium and cerium minerals have been found. Some beautiful transparent topaz crystals have been found near Tapa, south of Campar. Gold also has been found in small quantities in the tin alluvium.

It is probable that all these minerals once existed *in situ* in the rock in more or less close association with the tin. Certain other minerals, such as iron pyrites, chalcopyrite, bornite, and arsenical pyrites, which occur with the tin in the rock, are rarely seen in the alluvium, as they have decomposed and mostly disappeared during the erosion of the rock, though rusty masses of these sulphides, partly decomposed, and associated with quartz, often occur in alluvium which has not been transported far from its source.

Occurrence of tin ore in the rocks of the Kinta district.—Though the tin mined on the peninsula comes practically all from the alluvium, yet cassiterite also occurs in various places *in situ* in the rocks of the region. It is most often found in granite, but also occurs in the limestone and sandstone. It has been worked in a few localities, notably in the granite at Sorakai in Perak, and at the Rin mine in the Jelibu district in Selangor, while at Chongkat Pari in Perak, it has been worked in limestone. None of these efforts, however, have as yet been more than partially successful, and most of them have eventually failed, as the ore is in too scattered a condition to pay to work. Hence, though tin is frequently found in the rocks as well as in the alluvium, mining is mostly confined to the latter. It seems not impossible, however, that deposits may yet be found in the rock that can be profitably worked.

Where the tin is seen *in situ* in the granite, it occurs in pockets, small veins, or a combination of stringers intersecting each other in various directions in the form of a network, while

elsewhere the rock is simply impregnated with particles and crystals of cassiterite over certain areas. The tin is associated with quartz, tourmaline, fluorite, and the other minerals already mentioned, especially iron pyrites and arsenical pyrites, which often occur in very considerable quantities, and with smaller quantities of chalcopyrite. At Sorakai, some three miles southwest of Ipoh, two shafts were sunk on small seams of tin ore in the granite by an English company, but operations did not prove profitable and the works are now closed.

Tin in the limestone is probably rarer than in the granite, as

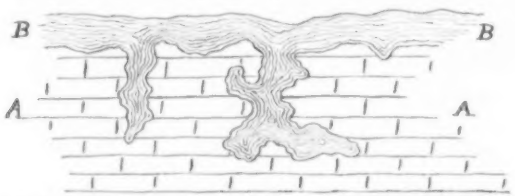


FIG. 4.—Section showing occurrence of tin-bearing alluvium at Chongkat Pari, Perak, Malay peninsula.

Chongkat Pari was the only case seen or heard of by the writer where it had been clearly proved to exist in that rock, while tin in the granite is of common occurrence. Chongkat Pari is two and a half miles southwest of Ipoh, and the region has been extensively worked for alluvial tin. The bed-rock is limestone, and the alluvium occurs in hollows and caves in the leached surface of this rock. (See Fig. 4.) It is from 1 to probably 20 feet in depth, of a reddish-brown color, and contains many large ferruginous masses, probably resulting from the oxidation of iron-bearing sulphides common in the limestone. At the mine of the Leh Chin Tin Mining Co. at this locality tin occurs not only in the alluvium, but also *in situ* in limestone. It is found along a zone of fracturing, marked sometimes by sheeting, running in a general direction of north northeast and south southwest, and dipping steeply to the west northwest. The ore occurs as cassiterite along the zone of fracturing, sometimes as an impregnation in the limestone, sometimes as lenses or irregular pockets from 4 to 24 inches in width, and sometimes along the

cracks in the rock, either longitudinally or transversely with the zone of fracturing. (See Fig. 5.) It is associated with large quantities of iron pyrites and arsenical pyrites, and smaller quantities of chalcopyrite and bornite, with some rhodochrosite. On the surface, limonite and malachite are found in the leached hollows of the rock, having been derived from the oxidation of the iron and copper sulphides. The deposit has been opened by

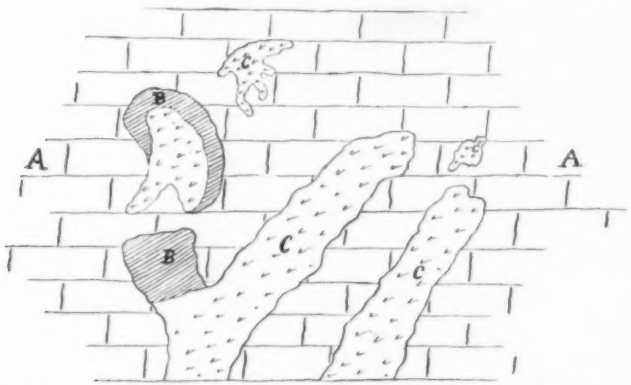


FIG. 5.—Section showing occurrence of tin in limestone at Chongkat Pari, Perak Malay peninsula.

a cut about 20 feet in depth in the limestone, but not much ore has been mined, as it has not yet been found in large quantities.

A few miles southeast of Ipoh, on the road to Gopeng, are a number of limestone hills rising several hundred feet above the valley. On the summits of some of these tin is said to have been found in the soil. It has yet to be determined, however, whether these deposits have been derived by decay *in situ* from tin deposits in the limestone, or whether they are the remains of old alluvial deposits transported there from a distance before the hills were formed. (See Fig. 6.)

At Bruseh, near Tapa, in Perak, tin has been found in thin seams and films along the lines of bedding in a soft, fine-grained, friable sandstone, which bears every evidence of being a comparatively young rock, and it seems probable that the tin in it was derived from tin-bearing solutions from the older rocks

percolating along the bedding planes. This special locality was not visited by the writer, but specimens of the ore and the rock were seen.

Origin of the tin deposits of the Kinta district.—The question of the origin of the tin deposits includes the occurrence of both the tin in the alluvium and the tin in the rock. The tin in the

FIG. 6.—Limestone bluffs southeast of Ipoh, Perak, Malay peninsula.

alluvium has clearly been derived by erosion from the tin in the rock, as is proved by the following facts:

1. Tin in noticeable quantities is a constituent of some of the rocks of the region, especially the granitic rocks and sometimes the limestone.

2. The mass of the alluvium is composed of materials derived largely from the decay and erosion of the tin-bearing rocks of the region, and contains numerous pebbles and bowlders of these rocks.

3. Frequently granitic fragments, similar to the granite in

Tin mine near Tronoh, Perak, Malay peninsula, showing limestone bed rock underlying tin-bearing alluvium.

the surrounding hills and carrying cassiterite, are found in the alluvium.

4. The cassiterite in the alluvium, though in a fragmental condition, is of the same character as that in the granite and limestone.

5. The alluvium is as a rule richest in tin, and the fragments of ore are largest, near the areas of tin-bearing rocks.

6. The characteristic minerals associated with the tin in the alluvium are the same as those associated with it in the rock, except in the case of the easily altered minerals, such as the iron and copper sulphides, which have usually been decomposed in the decay of the rocks, and therefore do not often appear in the alluvium, though partly altered masses of these minerals are sometimes found in the alluvium.

Such facts as these leave no doubt as to the origin of the tin in the alluvium. As regards the tin in the rocks, it may be said that in the granite, the occurrence of the cassiterite in veins, stringers, networks, etc., along lines of fracturing, are strong evidences of aqueous deposition of the ore; while the occurrence as an impregnation in the rock where no marked fissuring occurs may be due either to segregation during a more or less molten condition of the rock or to aqueous concentration in a solidified rock. It is possible that the tin was originally a disseminated constituent of the granitic rocks; and in places its concentration may have been due to segregation from a molten mass, but there can be no doubt that some of the concentration, as at present seen, was due to water action after the solidification of the rock.

The tin in the limestone was probably also deposited from solution. It does not seem probable that it was derived mechanically from the erosion of the granite during the deposition of the limestone formation, as it does not occur in the manner of a fragmental deposit, but in seams and clusters along lines of fracturing. Moreover, it is accompanied by iron pyrites, chalcopyrite, arsenical pyrites, etc., just as in the granite, and this would probably not be the case had the tin been detrital, as the iron sulphides in the granite would have been largely decomposed before being enveloped in the limestone. It seems prob-

able, therefore, that the tin in the limestone was deposited from aqueous solution in the same way as at least part of the tin in the granite. It is possible that the tin-bearing waters that deposited the ore in the limestone may have derived their metalliferous contents by solution from the disseminated tin in the granite; and this may account for the rarer occurrence of tin in the limestone than in the granite, for if the latter was the original source of the solutions that deposited tin in both rocks, the granite might get more of the deposition than the limestone, which was less close to the source of the solutions.

The tin found in the bedding planes of the sandstone near Tapa, seems, as already stated, to be a later deposit derived by solution from the older deposits in the granite or limestone.

Commercial features of tin-mining in the Kinta district.— Most of the mines of the Kinta district are operated by Chinamen, and the work is generally crude;[1] but in some localities, like Gopeng and elsewhere, English companies work the mines, while at Campar a French corporation carries on large operations; and in such cases the work is carried on in a more systematic manner. The laborers are mostly coolies from southern China and Indians from the east coast of India. The native Malays do not do much work, and Europeans cannot stand hard work in this climate. The coolies are the most numerous laborers, and here, as elsewhere in southeastern Asia, they are always found where there is any hard work to be done.

The tin-bearing alluvium is worked mostly in open cuts or large pits, except where the covering, or "overburden," of barren ground is very thick, when sometimes shafts are sunk through it to the tin stratum. Most of the workings, especially those of the Chinese, are only very shallow excavations on account of the difficulty of handling the water found at a depth. The average of the Chinese pits is probably not over about 40 feet in depth, though the enterprising Chinese mine-owner, Mr. Foo Choo Choon, reached several times this depth in his mine at Tronoh before he sold it. Some of the more progressive Chinamen

[1] The systematic operations of Mr. Foo Choo Choon, under the management of r. John Addis, are an exception to the usual crude methods of Chinese mining.

have lately introduced pumps to handle water, but even yet it is not uncommon to see the water raised from a shallow pit by a chain of buckets operated by a human treadmill, worked by the feet of two or three men. (See Fig. 7.)

The tin alluvium, after being mined, is carried to the surface in small baskets hung on both ends of a stick suspended on a

FIG. 7.—Pumping water by human treadmill, near Lahat, Perak, Malay peninsula.

Chinaman's back. It is then dumped into wooden troughs supplied with a stream of running water, where, if there is much clay present, it is stirred with shovels and hoes to separate the tin ore. If there is no clay or only a little of it present, the "tin dirt" is simply dropped into the trough in the running water. The materials are carried thence by the water into sluices, where the cassiterite and other heavy minerals sink to the bottom, and the sand, clay, and lighter materials are carried away by the stream. (See Figs. 3 and 8.) The sluices may

range from a few feet to several hundred feet in length, as the case may require, and are either made of wood or are cut in the sandy clay of the region. After a certain number of hours, the stream is stopped and the material at the bottom of the sluice is still further concentrated by hand panning in a flat wooden bowl not unlike in shape the ordinary sheet-iron American gold pan.

FIG. 8.—Washing tin ore near Tronoh, Perak, Malay peninsula.

(See Fig. 9.) The final process in the preparation of the ore is the separation, by hand-picking or by very expert panners, of the particles of magnetite and other heavy minerals associated with the tin, finally leaving a product varying from 69 to 73 per cent. in metallic tin. This ore is then sacked and hauled to market.

At Gopeng, the Gopeng Tin Mining Co. is using hydraulic monitors to handle the alluvium, in the same way as they are used in the gold placers of California. At Cacha, an English company has also erected a stamp mill with concentrating tables to crush and concentrate masses of ore. The alluvium here has

Eroded limestone surface in tin diggings between Ipoh and Lahat, Perak, Malay peninsula.

often been indurated by infiltration of iron compounds, while it also often contains masses of the original tin-bearing rock from which the cassiterite has not yet been liberated, so that crushing becomes necessary. At Sorakai, roasting, crushing, and concentrating machinery has been introduced by the Sorakai Tin Mining Co., an English corporation, to handle the ore mined in the

FIG. 9.—Women washing tin ore near Lahat, Perak, Malay peninsula.

granite at that locality, the roasting being necessary to drive off the arsenic in the ore. At Tronoh, some of the alluvium contains much clay which adheres closely to the tin, and the material is treated in large tanks with revolving paddles inside.

The tin was formerly smelted largely at local works in the various mining districts, and some of it is still treated in this way, but most of it is now smelted by the Straits Trading Co., which has a large smelting plant at Singapore. This company has great influence throughout the peninsula, and has established numerous agencies where tin is bought from the miners and sent to Singapore. The total production of tin on the Malay penin-

sula in 1901 was almost 47,000 tons, which is over half the tin of the world, while the production of the peninsula and the islands of Banka and Billiton together amounted to over three-quarters of the production of the world.

The tin lands on the peninsula are either bought or leased, and the government of the Federated Malay States imposes an export tax on tin ore of about 12 per cent. of its value. As tin is the main product of the peninsula, the tax affords a large income, which is the principal support of the government. The money derived from this source has been wisely expended, generally under British advice, in internal improvements. Excellent wagon roads have been built throughout the different states, and railways have been constructed in a number of localities. As yet the latter have not been connected throughout the peninsula, as they are being extended only so fast as funds are obtained to build them. It is expected, however, that before long the isolated lines of railway will be extended, so that there will be continuous connection from the extreme southern end of the peninsula at the town of Johor to the Siamese boundary on the north.

R. A. F. PENROSE, JR.

PHILADELPHIA,
February 3, 1903.

THE SIERRAN VALLEYS OF THE KLAMATH REGION, CALIFORNIA.

In a series of papers recently published[1] the writer has traced the development of the present topography of that portion of the Klamath mountain region which lies south of the Klamath river, terminating the story with a great uplift at about the opening of the Quaternary era. This history comprised a sharp folding of the sedimentary formations and the injection into them of batholiths of peridotite, gabbro, and granite, at about the close of the Jurassic period; a profound denudation and leveling off by sub-aerial processes in early Cretaceous time; a submergence of the border of the province in late Cretaceous time; a post-Chico deformation, throwing the entire region into a series of deep elliptical basins; a probable partial peneplanation, the product, perhaps, corresponding to the Eocene peneplain of southeastern California; an uplift resulting in the erosion of broad basins whose floors were probably irregular; the production beneath the floors of these basins of broad, deep, canyon-like depressions, apparently the result of stream erosion; the filling of the depressions by thick accumulations of river-channel deposits and the more complete leveling of the basin floors; and finally the uplift, tilting, and erosion of these old alluvial deposits.

Along the western border of the Klamath province and in the adjoining portion of the Northern Coast Ranges, Mr. J. S. Diller has encountered a rich territory (for the physiographer) and has recently published his conclusions in an admirable paper entitled "Topographic Development of the Klamath Mountains,"[2] the result of several reconnaissance trips into that region. He identified, on the older rocks of the Klamath region, numerous remnants of an uplifted and dissected plain of erosion, the Klamath

[1] *American Journal of Science*, Fourth Series, Vol. XIV, No. 79, July, 1902; *Science*, Vol. XV, June 13, 1902, p. 951; Jour. Geol., Vol. X, No. 4; May-June, 1902, pp. 377-92.

[2] *Bull. U. S. Geol. Surv.*, No. 196, Series F, Geography, 31, 1903.

peneplain. Below the level of the peneplain he has found various remnants of a series of sandstones and gravels, the age of nearly all of which, on the basis of abundant paleontological evidence, is placed late in the Miocene period. Some of these sandstone areas were uplifted, deformed, and planed off by stream erosion, producing a peneplain (the Bellspring), which is practically continuous with the Klamath peneplain developed on the older rocks, making it apparent that the latter was not materially disturbed until long after the deposition of these supposed late Miocene sediments.

Then the country was uplifted to the amount of 500 feet near the coast, but increasing inland, and there was locally developed a lower peneplain, which Mr. Diller has named the Sherwood. I am unable positively to identify the late Neocene grade level which I have observed in the Trinity basin with either of Mr. Diller's two main pleneplain levels, as there has apparently been an unusual deformation in the vicinity of the south fork of Trinity river, and I am not sufficiently acquainted with that region to give it its true value. The reader is referred to the map accompanying Mr. Diller's paper for the geography of the territory herein discussed.

The few short sections of late Neocene river channels which are known in the southern portion of the Klamath region are evidently mere remnants of an extensive system which must have been developed over the entire territory —a system comparable with the Neocene channels of the Sierra Nevada region. In the latter province there was an uplift without much deformation other than a gentle westward tilting. In the Klamath region, on the contrary, the differential uplifting took the form of broad arches. This may be likened to the arching of the Coast Range region to which is due the present parallel ranges separated by broad valleys, both northward and southward from the Bay of San Francisco. In fact, the arching of the Klamath region was part of the Coast Range system of late Tertiary and early Quaternary mountain-building. But in the Klamath province the entire territory was so greatly uplifted that the streams have trenched deeply beneath the troughs as well as into the arches,

and in consequence this arching is not so apparent in the topography as it is in the Coast Range region farther south. Indeed, it is only by studying the cause of the nearly complete destruction of the Neocene river deposits that one is led to recognize the fact and comprehend the nature of this arching.

The main Neocene channels for the most part had courses across this subsequently developed system of arches and troughs. Over the arches they have been carried so high above the present stream level that subsequent erosion has completely removed the old river deposits, and in most cases even destroyed the form of the old valleys. But where some of the main rivers crossed the deeper and broader troughs, their deposits were not lifted high enough above the present stream level to be completely destroyed by erosion. That is precisely the position in which we find the present Neocene remnants of the Trinity basin.

The direction of the axes of the arches and troughs is generally a little west of north. The preservation of twenty miles of the length of the old Trinity river deposit was due to the fact that the portion of it from Weaverville northward ran nearly parallel to a trough. The floor of the old channel rises very gradually toward the north, but where the channel deposit turns westward at Weaverville, the bottom rises rapidly. Apparently the floor of the channel at Weaverville has an altitude less than 1,000 feet above the sea and at the distance of three miles or less this has risen to probably 2,500 feet above sea-level.

The Weaverville Neocene area terminates northward about a mile south of Swift creek, but the broad basin in which it lies continues onward for many miles. The floor of the Neocene valley seems to have reached such an elevation at Trinity Center that the present Trinity river has trenched below it and removed its filling. It is probable that the summit of the low hills just west of Trinity Center reaches nearly or quite to the level of the floor of the old channel, and some of the river deposits near the top of these hills may be actual remnants of the Neocene deposit. The present river valley is abnormally wide at this point, which is due to the fact that here the old and new courses coincide, and further that there was at this locality

even in Neocene times the junction of the main Trinity river and the east fork of Trinity river.

I think I can trace the old valley up the main Trinity river to and beyond the mouth of Coffee creek, a distance of half a dozen miles from Trinity Center. There are near the river a number of small mountain ridges rising to about the same height. Back of them the slopes of the high mountains rise very abruptly. Usually this does not indicate a halt in the down-cutting of a deep mountain valley, because the tributary streams in approaching a trunk stream ordinarily reduce the summits of the intervening ridges to much lower levels than the main divides, producing the appearance of a basin, beneath the floor of which has been trenched a later system of valleys: but in this case the observer gains the impression that the ridges near the river have sufficient regularity in height to indicate that they are remnants of the floor of an old valley which was several times as wide as the present river valley. This apparent old valley floor rises upstream more rapidly than the present river, and before it reaches the point beyond which later erosion has so completely destroyed it that one fails to recognize a trace of it, the elevation above the river may be a thousand feet.

For a long time I have entertained the idea that the old Trinity river drained Scott valley. There is no definite evidence of this, but a number of facts in its favor. The abrupt termination of Scott valley at the southern end indicates differential uplift of the Scott Mountain region on the south. This we may call the Scott Mountain arch. The Trinity Neocene valley distinctly rises on the southern slope of this arch. On the summit of Scott Mountain there is a depression which may be a portion of the old valley floor. In that case the amount of the differential uplift would be between 2,000 and 3,000 feet. Some of the important tributaries of Scott river (which flows north), have southerly courses, hardly explainable by the known structure of that region, and suggest a reversal of the direction of drainage in the main valley.

The new valley trenched by Trinity river between Trinity Center and Junction City has an average depth below the late

Neocene grade level of about 1,300 feet. The tributary streams on the west kept pace with the main river in cutting channels through the rock barrier between the old and new valleys, and they have eroded deep canyons into the gravel deposit of the latter. Stewart's Fork and Rush creek have each cut down about 1,600 feet. Weaver creek was especially active and was favored by finer material in the broad portion of the old valley, so this small stream excavated a basin three or four miles in diameter and at least 1,000 feet in average depth. As a means of draining this basin it excavated in micaceous quartz schist and serpentine, a narrow, crooked canyon valley five miles in length and over 1,000 feet in depth.

From Junction City to North Fork, six miles, the present course of Trinity river seems to coincide with the old course. It is directly in line with the last mile of the old channel deposit of the Weaverville area, and there is no other apparent outlet among the hills for the old valley. But between Weaverville and the La Grange hydraulic mine (the latter at the extreme western end of the gravel deposit), as already mentioned, the bed-rock floor of the channel rises rapidly, and westward from the mine it is so elevated above the present drainage level that erosion has completely destroyed the gravel deposit. Yet the influence of the old channel on the present valley is still apparent as far as North Fork; for the Pleistocene river, being favored in this portion of its course by a broad valley filled with easily eroded gravel, and having cut down deeply among the bed-rock hills, although not nearly to the present water-level, has been enabled to greatly widen its present valley. Such abnormal widening of the present Trinity valley does not occur except at the few points where independent evidence indicates clearly that there the old and new courses coincide.

One mile below North Fork, the Trinity river enters a narrow gorge five miles in length and perhaps 1,500 feet in depth. The extreme narrowness of the gorge is explained by the fact that the river is traversing a resistant formation, a great gabbro batholith. However, it is beyond dispute that this gorge does not represent the Neocene valley which, even in this hard

formation, must have been many times wider than the present valley. Yet I think the old valley followed this course, but has been carried up so high by uplift and deformation as to have been completely destroyed by erosion.

After passing the gabbro, the Trinity valley is wider again, and low ridges near the river with the higher mountain ridges some considerable distance back, suggest that the present small valley is trenched beneath an older larger valley. I would not be certain of the value of the evidence, had not Mr. Diller discovered one of the Neocene remnants in this basin.[1] It contains lignite and is otherwise similar to the Neocene deposits of Hay Fork and Hyampom valleys. A short distance below Big Bar the river enters a veritable gorge which it follows for about thirty miles, nearly to Hawkin's Bar, and I am practicaily certain that this is not the old course of the stream. The gorge widens where it crosses the Paleozoic slates, but where it is trenched in gabbro and allied Plutonic rocks, as it is through most of its course, it is extremely narrow. In many places the slopes rise directly from the river's edge on both sides and continue up as steeply as the loose material will lie to the tops of the neighboring mountains, probably 3,000 feet above the river. Rock precipices are common, and often the trail has to climb hundreds of feet above the river to pass a rocky point. There are no shoulders on the slopes of this valley, and nothing to indicate complexity in its history. It is a simple Pleistocene valley of the gulch type 3,000 feet in depth.

I have some confidence that the Neocene valley followed the present course of the river as far as Big Bar, but what was its course beyond that point is a problem. It is probable that it went more directly west for a few miles than does the present river beyond this point and then turned to the southwest; there is some evidence of this, but it has not been studied in detail. On the line between Big Bar and Hyampom valley there is a depression among the mountain summits which may mark the line of this old valley. Nearly midway is Corral valley, which is described as a flat-bottomed, basin-like depression about a mile

[1] *Fourteenth Annual Report, U. S. Geol. Surv.*, Plate XLV, and p. 419.

in width, drained by an insignificant creek through a narrow valley. From the description, it is probably a short section of the bottom of a Neocene valley, the gravel filling of which has been cleaned out by erosion. It is also probable that at or in the vicinity of the present Hyampom valley the old Trinity river was joined by the Hay Fork river.

It is apparent that the deformation of the Neocene surface in the western part of Trinity county took the form of a broad arch. It is believed that this extended north through Siskiyou county, across the courses of the Salmon and Klamath rivers. It is marked by the deep, narrow, rocky gorges of all the streams which cross it. These gorges invariably have the gulch type, so characteristic of Pleistocene erosion in the Klamath region, and their comparative youthfulness is beyond dispute.

Hay Fork stream, between the Hay Fork and Hyampom Neocene valleys, is said to flow for miles through a deep rocky gorge whose relative narrowness is not satisfactorily explained by the resistant properties of the formations trenched. New river, a northern tributary of Trinity river, has trenched a deep valley into the supposed arch. The New river country, although not high and rugged as the Sierra Costa mountains, is so extremely broken as to be almost inaccessible. An effort was made to construct an especially well-graded trail along New river, yet in places it climbs nearly a thousand feet above the stream to get around a rocky point. The valley is characterized by immense landslides, which form rough terraces and at one place supply enough level land for a farm. These landslides are the result of the very rapid down-cutting of the bottom of the valley. The phenomena witnessed throughout this region tell of the newness of the cycle of erosion. All the valleys are of the same gulch type as those of Trinity Mountain, which are known to post-date the uplift of the Neocene deposits. In the latter region, the vertical element of the erosion hardly exceeded 1,500 feet, but in the lower Trinity and New river country, it was not less than 3,000 feet.

The gorge of the Salmon river between Bennett's and its mouth seems to belong to the same category as those just mentioned. Perhaps the most magnificent example of the class is

that of the Klamath river, which has attracted some attention and given rise to speculation as to its origin. I have never visited it, but it is described as just such a narrow, steep-sided, and very deep valley as that of the lower Trinity. The mountains near the so-called canyon rise to altitudes of 6,000 and 7,000 feet, and the valley has a depth below these higher summits of 4,000 to 5,000 feet. Probably 3,000 or 4,000 feet of this erosion belongs to the time following the deformation of the Neocene surface. I suggest in explanation of it the same hypothesis as has been applied to the lower Trinity, namely, that the Klamath river flowed in practically its present course in late Neocene time, and that during the subsequent orographic disturbance a broad arch was formed athwart its course, but the river maintained its position by cutting a deep valley through the arch. Virtually the same opinion has been expressed by Mr. Diller.

In the case of the Trinity river, there must have been first a short, rapid tilting of the Neocene baselevel to cause the river to migrate and then followed a long, gradual uplift; for, had the movement been a simple one and gradual, the river would not have abandoned its course, and had it been rapid throughout, the river would not have been able to maintain its course by cutting a gorge through the arch.

The south fork of Trinity river and the main Trinity river below Hawkins' Bar roughly mark the western limit of this arch. The Post Creek mountains stand on the crest of the arch south from Hay Fork river. From their summit southwestward to near the south fork of Trinity river there is a long, comparatively gentle slope of the general mountain surface, then a sudden descent into the canyon of the river, and on its southern side a comparatively abrupt rise of about 3,000 feet to the even-crested summit of South Fork Mountain. There is here apparently a fault with a throw of several thousand feet or a sharp monocline. I believe that I am correct in referring the long southwestward slope northeast of the river to the late Neocene grade level of Trinity valley, but I am not so sure that it is an equivalent of the Klamath peneplain remnant at the summit of South Fork Mountain. The Hyampom Neocene deposit lies

in this relatively depressed area and has an elevation of about 1,400 feet. I am inclined to the belief that before the derangement of the drainage the Trinity and Klamath rivers had independent courses across the area now occupied by the South Fork Mountain, and that this mountain gained topographic prominence by faulting or folding so rapidly that the drainage was deflected toward the northwest along the line of the fault or fold.

The later system of valleys in the Klamath region is comparable to the Sierran valleys of the Sierra Nevada region. In the latter area only in very exceptional instances has the erosion since the uplift of the peneplain exceeded 3,000 feet in depth. The resulting valleys are equally as narrow, when in a formation of like resistant properties, as in the more northern region. Indeed, the evidence of age is rather in favor of the Klamath than the Sierra Nevada region, for the valleys or gorges or canyons, as we may choose to call them, more thoroughly dissect the surface in the former area. However, the contrast is not great when the comparison is made with the Sierra Nevada region south of the Tuolumne river. The latter is more thoroughly dissected than the northern Sierra region because the average slope of the surface is greater. The slopes in the Klamath region, by reason of the arching, were at least as great as in the southern Sierra region, and the remarkable similarity in the nature of the dissection, and the depth and width of the valleys eroded, unmistakably point to a like age. To assert that the inception of the last great uplift of the Klamath region occurred at a time materially antedating or succeeding the inception of the last great uplift of the Sierra Nevada region, one must disregard the most positive evidence to the contrary. I want to emphasize very strongly that there is the best of reason for correlating the last great arching of the Klamath region, which deranged the drainage and caused the erosion of the new valleys, with the westward tilting of the Sierra Nevada region which initiated the canyon cutting.

As already intimated, I consider the arching of the Klamath region as contemporaneous with and merely a portion of the last

great folding of the Coast Range region. This occurred at the close of deposition of the Merced series and was the opening event of the Quaternary era. Last winter I recognized[1] in Piru canyon in southern California a valley definitely comparable in size to Sierran canyons of the Sierra Nevada region that have been eroded under like conditions. This canyon dates entirely from a time succeeding the deposition of a late Pliocene formation, apparently an equivalent of the Merced series.

The erosion of the Sierran valleys of the Klamath region has continued practically uninterrupted to the present day. With a few unimportant exceptions, there are no well-marked terraces in the lower mountain valleys to indicate halts in the down-cutting, although locally, through the vicissitudes of erosion, remnants of the alluvial deposits are left for a time at some height above the streams. They are commonly known as "old channels," and many of them have been opened as hydarulic mines. Naturally, they are most abundant at low levels, but occasionally one may be found as much as 500 feet above a stream. Sooner or later all will succumb to the undermining of the slopes, and new ones will be formed at yet lower levels.

The exceptions worth noting are in the vicinity of Hawkins' Bar on the lower Trinity river and at the junction of the north and south forks of the Salmon river. These streams there flow, at present, in very narrow rocky canyons trenched in the bottom of much broader, flat-bottomed, gravel-floored valleys. The latter remain intact over comparatively extensive areas and the trenching is quite recent. Whether this is purely a local development or a persistent feature in the direction of the coast I am unable to say.

Late in the Quaternary era there was developed by subaerial agencies on the northern border of the Sacramento valley a plain several miles in width, which traverses the edges of highly inclined pre-Cretaceous strata. Some disturbance, probably a slight and temporary depression, mantled this plain with stream gravel, forming the Red Bluff formation. The Red Bluff grade level is traceable at several points for a distance of several miles

[1] *Bull. Dept. Geol., Univ. Calif.*, Vol. III, No. 1, p. 9.

into the mountain valleys, but in the remainder of the Klamath region it is unrecognizable. At many places there are gravel-covered benches which may represent the Red Bluff level, but they are short and do not fall into a definite system. They may just as well represent some subsequent stage in the down-cutting of the valleys.

Below Lowden's Ranch on the Trinity river the valley contains a heavy deposit of gravel, the genesis of which I do not know, but several features of this locality are evident and interesting. An inspection of a map of Trinity county will attract attention to an unusual meandering course of Trinity river for about ten miles below Lowden's. Nothing similar occurs anywhere else in the Klamath region. The meanders are like those of a sluggish stream on a broad flood-plain. However, this portion of the Trinity valley is quite narrow, and the crookedness of the river is due to the crookedness of the valley. It is a meandering valley cut down about 500 feet below the surface of the gravel deposit mentioned above. The gravel ridges on the inside of the curves scarcely anywhere reach the original surface, but we can reconstruct the old flood-plain on which these meanders originated. It was the floor of a valley several miles wide, which was bounded on either hand by steep mountains which rose 500 to 1,000 feet above it. I am not certain that we are not here dealing with another remnant of the Neocene valleys and their alluvial filling,[1] but the meanders themselves certainly originated after the uplift and rearrangement of the drainage system. Perhaps the new Trinity river used an old Neocene deposit as a stage on which to perform its evolutions.

OSCAR H. HERSHEY.

BERKELEY, CALIF.,
January 28, 1903.

[1] Diller has mapped this gravel deposit in the *Fourteenth Ann. Rept. U. S. Geol. Surv.*, Plate XLV, as one of the Neocene areas of Trinity county, but its relation to the other deposits is not clear.

ANTICLINAL MOUNTAIN RIDGES IN CENTRAL WASHINGTON.[1]

THE recent revival of interest in the Basin range type of mountain structure has caused the review of many of the data bearing upon that subject. Mountain ridges of the same type were early described by Professor I. C. Russell[2] as occurring over an area somewhat removed from the Great Basin. Similarity of climate and the consequent presence of desert conditions east of the Cascade mountains produce a certain resemblance of central Washington to that region farther south, and the great expanse of basalt lava also renders it natural to consider this area as in a way the continuation of the northern portion of the Great Basin. More questionable, however, is the assumption that the type of mountain uplift commonly believed to be so persistent in the Great Basin is likewise characteristic of central Washington.

A critical consideration of the earlier descriptions of the structural features of central Washington is deemed essential at the present time for two reasons. In the first place, the published results of the geologic reconnoissances, containing as they do the first descriptions of the area, possess the authority that naturally goes with priority. Thus these statements of geologic observation and inference come to be generally accepted and cited by writers who have occasion to refer to the region;[3] and this general acceptance prevails, although quite different descriptions of the area have been published which are based upon later geologic studies of the same area.[4] It is therefore desirable to state distinctly the opposition of later field observations to the statements based upon earlier work. This direct

[1] Published by permission of the Director of the U. S. Geological Survey.

[2] "A Geological Reconnoissance in Central Washington," *Bull. U. S. Geol. Surv.*, No. 108, 1893.

[3] An example of this can be found in the *Third Report, Bureau of Soils*, U. S. Dept. of Agriculture, p. 392, 1902.

[4] *Water Supply and Irrigation Paper, U. S. Geol. Surv.*, No. 55, pp. 23, 24, 1901.

comparison of observations must be made that the reader may have the evidence before him. In the second place, this statement of the disagreement between the results of earlier reconnaissance and later detailed mapping is important in that it may contribute something in the way of suggestion to the broader problem of determining the origin of the Basin ranges. In the solution of such problems, the observations, largely physiographic in character, made in the course of a rapid reconnaissance, may be found later not to be in accord with the geologic data secured during a careful survey of the same area or a portion of it. The methods employed in reconnoissance work are of necessity quite different from those possible in the mapping for folio publication, when a topographic base map is available and the area is thoroughly traversed. Thus, the plea for a rehearing of the evidence does not concern the witnesses so much as the different conditions under which their observations were made.

The Ellensburg quadrangle in central Washington has been mapped geologically by the writer and Mr. Frank C. Calkins, and the results of that survey are incorporated in Folio No. 86 of the *Geologic Atlas of the United States*. The area is one of considerable geologic interest, as it lies in the zone intermediate between the Cascade mountains and the Great Plain of the Columbia. It is natural, therefore, that related as this region is to both of these distinct topographic provinces, its geologic study should yield results bearing upon the structure of both the mountains on the west and the plateau on the east. The area is likewise of interest as the one visited earlier by the reconnaissance geologist and as including many localities the descriptions of which apparently contain the basis of generalizations concerning the prevalence of the Basin range type in central Washington. In the following pages such descriptions will be cited, followed by comment based upon the results of the later work. For the full discussion of the geology and physiography of this quadrangle the reader must be referred to the Ellensburg folio, since the present article can contain only such points as bear directly upon this discussion.

A brief statement of the geology may serve to introduce the

discussion of the structural features. Only two important formations are involved, and both extend eastward to the Columbia. The older is the great series of Miocene basalts, measuring several thousand feet in thickness, and this is overlain by Miocene sediments 1,500 feet thick in the best-observed section. To these two series the names "Yakima basalt" and "Ellensburg formation" have been given. Reference will also be made to the Wenas basalt, which consists of one or more thin lava flows interbedded with the lower portion of the Ellensburg formation, unimportant except as it often affords more exact datum planes for the determination of structure. Topographically the region is one of moderate relief, and the general absence of erosion subsequent to the latest deformation of the region is a result expressive of the aridity of the climate.

The first recognition of the Basin range structure in central Washington is given by Professor Russell in these words:[1]

> All of the formations mentioned in the preceding section were originally spread out in essentially horizontal sheets, but since the youngest member in the series was laid down they have been broken into blocks, and the blocks tilted and upturned so as to form prominent mountain ridges with horizontally floored valleys between. A structure has thus been given to the beds on which depends nearly all of the present topographic diversity of the region. . . . .
>
> Briefly stated, the main structural features in our field are (1) narrow, sharp-crested ridges having a prevailing east-and-west trend, due to the upheaval of the borders of orographic blocks; (2) broad and comparatively gentle north-and-south elevation, produced apparently by an arching of the strata, parallel to and probably of the same date as the much greater uplift forming the Cascade mountains; (3) regions where the rocks have been but little disturbed and now form plains and valleys.

The author distinguishes monoclinal ridges and monoclinal folds. Of the former he states:

> The prevailing and most typical structure has been produced by the breaking of the strata and the upturning of the beds on one side of the lines of fracture. The fragments, more or less regular, into which the rocks have been broken are termed orographic blocks. (P. 28.)

The monoclinal folds are thus described:

[1] *Op. cit.*, pp. 28–31.

Besides monoclinal ridges there are other types of mountains in the region traversed which are not so simple in their structure. These are long, narrow ridges which were formed by an arching of the strata without breaks. (P. 29.)

In a later publication[1] the structural features of this area are again described:

The monoclinal structure so characteristic of the western portion of the region known as the Great Plain of the Columbia, and of its southern extension in the Great Basin, due to the tilting of fault-blocks, was found to extend to the mountains on the west. As one approaches the Cascade range from the east, the tilted blocks, the upturned edges of which are short mountain ridges, become of larger size, and form the immediate foothills of the main range. This merging of the structure characteristic of the interior basin with the mountains bordering it on the west, so far as my own observations extend, is more pronounced in central Washington than elsewhere.

A third reference to this region is made in a later report by the same author:[2]

Again, to the east of the portion of the Yakima valley just referred to, as described in a previous report, there are several mountain ridges, such as the two bordering Moxee valley on the north and south — known, respectively, as Selah ridge and Yakima ridge — and Satas ridge, which forms the northern border of the tilted plateau termed Horse Heaven. Each of these ridges is due mainly to the tilting of a block of the earth's crust, capped with basalt, along lines of fracture. This series of faults, and perhaps in part of monoclinal folds, trends nearly east and west, and some of them cross the Columbia, as, for instance, the break on the north border of Saddle mountain.

Five ridges of the topographic type mentioned above cross the Ellensburg quadrangle, and, by way of comment on the general statements given above, these ridges may be considered separately, quoting as far as possible any specific mention that may have been made of them in the earlier reports.

The southernmost of these five ridges is Yakima or Atanum ridge, mentioned in the preceding paragraph. In the earlier report[3] this ridge is more accurately described as having "an arched structure throughout" and belonging to the class of "monoclinal folds," but later (p. 52) the possibility of "a break along portions of the northern base" is mentioned. The observations

[1] *Volcanoes of North America*, 1897, p. 248.

[2] "A Preliminary Paper on the Geology of the Cascade mountains in Northern Washington," *Twentieth Annual Rept., U. S. Geol. Surv.*, Part II, p. 138.

[3] *Bull. No. 108*, p. 29.

made by Mr. Calkins and the present writer along this east-west ridge convinced us that the structure is that of a broad arch, somewhat unsymmetrical, in that on the northern limb the dips are steeper than on the opposite side, and for short distances the strata are even overturned. This anticlinal structure in the basalt flows is well exhibited at Union Gap, where the Yakima river has made a steep-sided cut, a mile in length and 800 feet in depth, across the ridge.

The next ridge to the north is Selah ridge, also mentioned above. In the earlier description (p. 29) it is stated that here "the arch is broken longitudinally and the ridge assumes the faulted character described in the preceding paragraph," *i. e.*, it is a "monoclinal ridge." A more detailed description is given on a following page (p. 54):

> The structure of Selah ridge is too complex to be described intelligently without the aid of map and detailed section, but these are not to be had on account of the lack of an accurate survey. The ridge is an exception to other similar uplifts in the same region, for the reason that it changes from a monoclinal ridge at the west, where the dip is toward the north, to a monoclinal ridge at the east having a gentle slope to the south. The general form of the ridge is that of a long, narrow arch, broken at the west end by a fault on the south side, and by another fault on the north side, for the greater portion of its length.

On the preceding page the structural relations at Selah gap are considered somewhat more fully:

> In the west end of the ridge, separated from the main portion by the deep transverse canyon cut by Yakima river, the east side of the fold is wanting. It may have been cut away by the Naches, which flows along its base, but more probably was carried down by a fault which may have been continuous with a break to be seen on the south side of the ridge and east of the Yakima. There is also a cross-break running north and south which determined the course of the Yakima river. This is shown by the lack of correspondence in the dip of the light-colored John Day beds (Ellensburg formation) occurring on the sides of the canyon.

The detailed study given to this locality when it was mapped afforded no reason for considering that Selah ridge possesses a structure more complex than other ridges of the vicinity. There appears to be no necessity for dividing it "into sections having various structures." It is true that farther west where it merges

into the basalt plateau it is monoclinal in part, but there it is hardly a distinct ridge, becoming such only as it assumes an anticlinal structure. In the vicinity of Yakima river, where the descriptions quoted above apply, this anticlinal structure is pronounced, and on the edge of Selah gap the anticline is seen to be flat-crested with steep sides. For two miles west of Yakima river the south side of the fold—erroneously termed the east side in the last quotation—is cut away by Naches river, while similar cliffs have been produced east of Selah gap on both sides of the ridge by meanders of Yakima river. That these steep escarpments in no wise indicate faulting seems evident by the presence of efficient agents in these rivers at the base of the cliffs, but is demonstrated by the presence of a remnant of the southern limb of the fold south of Naches river. Here the Ellensburg sandstone occurs with a steep dip to the south, just where this portion of the anticline should be found, while east of Selah gap, immediately beyond Yakima river, the fold is also perfectly preserved. The presence of the Wenas basalt interbedded with the sandstone makes it possible to work out the structure with considerable certainty. As regards the "cross-break running north and south," this appears to be explained as a slight sag or fold, the anticline pitching differently on the two sides of Selah gap. In brief, then, the assumption that this ridge is due in any degree "to the tilting of a block of the earth's crust capped with basalt along lines of fracture" seems unwarranted by observed facts. The anticlinal structure is plainly exhibited, and in this respect the ridge is no "exception to other similar uplifts in the same region."

The ridge next to be treated is Cleman mountain, an uplift which, like those described above, crosses the Yakima, but is most prominent ten to fifteen miles farther west. This has been described as follows:[1]

> The Naches, for a score of miles at least above the mouth of Tiaton creek, flows through a deep canyon, bounded on the east by the precipitous face of a long, uplifted mountain mass having the topographic form of a great fault scarp, in which the inclination of the strata is northeastward. The

[1] *Bull. No. 108*, p. 65.

country about the upper portion of the Naches was only seen from a distance, however, and may have a more complete structure than is here suggested.

Here again the later field study has afforded conclusive evidence that the Cleman mountain anticline is complete, except for a distance of six miles along its southern slope, where a huge landslide has pushed into the canyon of Naches river below. However, it is along the lateral escarpment facing this landslide area that the best exposures of the structure are to be had.

Umptanum ridge succeeds Cleman mountain on the north, Wenas valley separating the two. North of this in turn is Manastash ridge, known also as the Beavertail hills. The reconnoissance description of this region follows:[1]

> The rocks on the head waters of Wenas creek are Columbia lava, broken and upturned in fault scarps, which merge into a general region of uplifts to the west, but become separated and well defined in traversing the desert country to the east. The ridges thus found agree in their principal features with nearly all the east and west ridges in Yakima and Kittitas counties. One of the lines of east-and-west faulting between Wenas and Kittitas valleys is marked by Umptanum ridge, which presents its bold escarpment to the northward. North of this, again, are the Beavertail hills, which are also a monoclinal uplift.

Umptanum ridge is perhaps the highest of these east-west ridges where it is crossed by Yakima river. The perfect arch of the ridge at Umptanum gap exposes a thickness of Yakima basalt exceeding 2,000 feet. The anticlinal structure is most evident, the fold being unsymmetrical, with the northern dips steeper. If any faulting is present, it must be of the nature of displacement on the plane between two sheets of basalt, but in any event, judging from the excellent section seen in Umptanum gap, faulting is of minor importance. Along the northern face of the ridge farther west there is a prominent outcrop of black basalt making a scar somewhat suggestive of a bedding fault. At another point, however, an even more prominent feature of this sort was seen in section, and the observation was conclusive as to the absence of any faulting. Thus, on the evidence of detailed study, the assertion is confidently made that in no

[1] *Ibid.*

respect is Umptanum ridge of the nature of a faulted monoclinal fold.

Manastash ridge likewise exhibits the anticlinal structure, unsymmetrical, and again with the steeper dips on the north limb. In the vicinity of Yakima river there is a fault present, as shown in the areal distribution of the formations. This fault, however, produces no scarp, and indeed crosses slightly the topographic axis of the ridge, showing the impossibility of its having any part in the elevation of the ridge. In fact, this fault belongs to a period of deformation antedating the uplift of these ridges to their present elevations. Throughout the region the orographic history has been more complex than is indicated in this article, where only those facts are cited which bear upon the points in question.

Farther east the Manastash ridge uplift unites with others to form Saddle mountain, which is cut through by Columbia river at Sentinel bluffs. The structure of Saddle mountain was described by Professor Russell as follows:[1]

> Saddle mountain, as previously mentioned, belongs to the series of monoclinal uplifts due to faulting, which extend eastward from the foothills of the Cascades. This long, narrow, sharp-crested ridge is perhaps the most remarkable of these uplifts, as it extends farther east than any of its companions and clearly reveals its structure where the Columbia has cut through it.
>
> It is there a well-defined monoclinal ridge, dipping sharply southward and presenting a bold scarp to the north. The dip of the strata of basalt of which it is composed corresponds with the gently sloping southern side. The line of fracture is on the north side of the ridge, and the steep northern face is a fault scarp. Toward the eastern end the fault scarp decreases in height and finally dies out, and the John Day beds pass over and conceal the Columbia lava. The dip of the strata on each side of the ridge toward its eastern end becomes about the same, showing that the fault passes into a fold.

Through the kindness of Mr. Frank C. Calkins, the following quotations are made from his description of the same locality from the manuscript of a water-supply paper now in preparation:

> The north face of Saddle mountain, where it overlooks the lower stretch of Crab creek . . . . suggests faulting in a very striking way. . . . . It is obvious that we must have here either a normal fault with the downthrow to the north or a sharp flexure, the downfolded portion having been removed by erosion, leaving only the nearly horizontal strata on either side. . . . .

[1] *Ibid.*, p. 96.

On the west side of the Columbia, opposite the mouth of Crab creek, the continuation of the mountain is bounded on the north, not by a cliff, but a steep slope. The mountain shows no outcropping horizontal ledges, but rising through the mantle of soil sloping back on the spurs and forward in the gulches can be traced the outcrop of one or more especially resistant beds of black lava, having a dip a little steeper than the slope. . . . . At another point twenty miles east of the mouth of Crab creek, the slope of the mountain was examined again and a similar state of things observed. . . . . The evidence demonstrates that there is here a sharp flexure and not a fault.

While the fact is not proven beyond doubt, I believe that this flexure, observed both east and west, was once continuous along the entire front of Saddle mountain, that the cliff along lower Crab creek is the product of erosion, and that the flexure is here concealed below the sediments in Crab creek bottom.

This citation of conclusions as to the orography of central Washington based upon reconnoissance observations and their comparison with the results of later and more detailed field work is believed to be justified by the result gained. Further evidence as to the true type of uplift is presented in the accompanying structure sections, Fig. 1. These are drawn to scale, and the structural features indicated are based upon dips observed along the line of section, and upon the general form of the different anticlines as exposed in the Yakima canyon section. The opportunity for direct observation of structure afforded in these gaps cut by Yakima river is exceptional and entitles the structure sections to considerable credence. The use of the scale 1 : 125,000 without vertical exaggeration renders the relief much less prominent than it appears to be in the field, but it is believed that a more accurate conception of structure can be obtained from these sections than from many drawn to illustrate the Basin range type, in which, as the author states, "the vertical scale is exaggerated and no attempt is made to represent the structure of the orographic blocks."

The type of deformation existing in central Washington is of interest in that enough is known of the geologic history to state the amount of load under which the rocks were flexed. Mention has been made of the two periods of uplift. In the earlier, which is believed to have been during either late Miocene or early Pliocene, the Yakima basalt may have been covered by 2,000

feet of Miocene sediments, the thickest section of the Ellensburg formation measuring 1,600 feet. Subsequent erosion, however, removed the Ellensburg, and even some sheets of the Yakima basalt over considerable areas, so that the later deformation was of the nature of flexing at essentially the present surface. This uplift began probably in the Pliocene and continued long enough so that even now erosion has not essentially modified the ridges of deformation. The exception to this statement is found in the water gaps of the Yakima and Naches rivers, in which cases

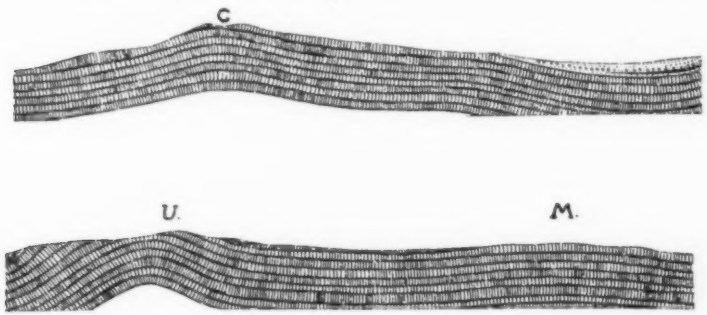


FIG. 1

streams coming from the more humid region to the northwest have possessed sufficient corrosive power to withstand the deformation forces and maintain their right of way across the uplifted ridges. The mechanics of such surface deformation would alone constitute an interesting subject of investigation. It is evident to any observer that a series of basaltic flows in which the columnar jointing is so common a feature would act quite differently under deforming forces than more rigid formations. The type of deformation found here is that termed by Van Hise[1] "joint folds." One distinction must be kept in mind, namely, that the joints in the Yakima basalt are not the product of the deformation forces, but owe their origin to contraction in the cooling lava. During the later deformation these thousands of joints may have been opened sufficiently to allow the production of the broad flexures of the basalt sheets. Adjustment along the planes between suc-

[1] VAN HISE, JOUR. GEOL., Vol. V, p. 191.

cessive lava sheets, as well as between the vertical columns, must reasonably be expected to have been important in whatever flexing took place. Such displacements, however, were at no place observed, and are doubtless on a minute scale, although of considerable importance in the aggregate.

A consideration of the cause of deformation of the nature described here would lead to the discussion of a much broader question. It would involve the origin of the Cascade range, the uplift of which is believed to belong to the same period as the production of these east-west ridges. Such a discussion will be in order after the results of detailed mapping over larger areas of the Cascade mountains are in hand. It may, however, be in accord with the purpose of this paper to take exception to certain assumptions as to origin with which the geologist apparently sometimes enters such a field. An example follows:[1]

> The arches were raised by a force acting from below upward, and not by lateral pressure which forced the strata into ridges and troughs, as is common especially in the Appalachian mountains.

This distinction between the supposed monoclinal structure with faulting and the more common type of deformation appears to be based in large part upon certain *a priori* hypotheses developed in the course of work farther south, viz.: tilted orographic blocks are expressive of lateral extension rather than lateral compression, and the region is one characterized by depression as well as by fracturing. Therefore, central Washington, like southern Oregon, was at once considered as characterized by deformation which involves extension rather than compression. It is now suggested that such assumptions are not the only ones that can be made to account for the facts. A glance at the structure sections will show this assumption of extension to be unsupported by the field evidence. The occurrence of overturned strata on the limbs of folds is, moreover, forcibly suggestive of some degree of lateral compression, while the fact that the Yakima cuts below the floors of several of the transverse synclinal valleys may be considered good evidence that these valleys are not sunken areas, but have simply been uplifted less than the bordering ridges.

[1] *Bull. No. 108*, p. 29.

The search for a force to supply this supposed upward pressure involves further difficulty (p. 29).

> Just what the action was which produced these arches it is difficult to determine. It is possible that volcanic rocks, escaping in a molten state through fissures in lower beds, raised the Columbia lava and superimposed beds into arches. In the continuation of the ridge cut through at Union gap, which forms the south wall of Moxee valley, molten rock forced up from below escaped through fissures in the Columbia lava, but raised the lighter beds above into a long, narrow ridge. In this instance the intruded lava has been clearly exposed by the erosion of a longitudinal valley along portions of the crest of the uplift.

In another place (p. 54) Selah ridge is cited as another possible occurrence of uplift by intrusion. "There are also reasons for suggesting that the scoriaceous basalt at the base of the section may have been a subsequent intrusion." In a careful study of the basalt section at the latter locality with a view to substantiate the earlier observation, the present writer failed utterly to find any reason for supposing any of the basalt intrusive. Both here and in the other locality cited the extremely scoriaceous character of the basalt was observed, but was taken by him to indicate the basalt to be extrusive rather than intrusive. Moreover, in both cases the basalt in question is superficial in position as compared with that shown in the deeper cuts of Union and Umptanum gaps.

Relative to the structural features of central Washington, then, the later and more detailed observations conflict with the results of earlier reconnoissance in these respects:

The mountain ridges described as monoclinal fault-blocks, tilted along lines of fracture, are found to be gentle anticlinal folds, with no evidence of faulting at any one of the several localities cited.

The assumption that lateral pressure had no part in this deformation is opposed by the structure section which shows compression, as well as by the occurrence of overturned strata on the sides of one of the synclines.

The hypothesis that igneous intrusions produced the deformation rests upon field evidence, which impresses the later observer as wholly inadequate.

GEORGE OTIS SMITH.

SOME ADDITIONS TO THE CARBONIFEROUS TERRESTRIAL ARTHROPOD FAUNA OF ILLINOIS.

INSECT remains of Paleozoic age, representing the advent of a class of organisms which is today the largest and most highly specialized of all animal groups, naturally possess an absorbing interest. Unfortunately but few localities have been discovered that yield these fossils, and these have produced but a small number of forms as compared with those of Tertiary and recent time. From the strata of Silurian and Devonian age, insect-remains are so extremely rare that but little can be asserted of them, the bulk of Paleozoic insects being from strata of Upper Carboniferous age. As might be expected, Paleozoic insects often combine in one individual, characters that at the present time are distributed among several orders, and for these synthetic forms which have no living representatives, the name Palæodictyoptera has been proposed by Goldenberg and followed by Scudder.

With the exception of two species preserved in the collections of the Chicago Academy of Sciences, all the material described in the present contribution is in the palæontological collection of the Walker Museum of the University of Chicago, and most of it is from the Gurley collection. With one exception, the specimens are all ironstone concretions, and nearly all are from the famous Mazon creek locality in Grundy county, Illinois. A portion of the collection studied has already been worked over by Dr. S. H. Scudder, and the results of his investigations have been published in a number of his papers, and all that is desired in connection with this portion of the material is to make known the location of the type specimens. Among the remainder of the collection there are several forms of very great interest.

The new forms here described are all more or less closely allied to those already known from America, and the classification here used is that elaborated by Scudder rather than

that of Brongniart which was based upon the quite different European insect fauna of Carboniferous times. Most of the new species here recognized are assignable to genera already known —an interesting fact which would indicate that at the early period when these insects lived there were but comparatively few types, and that the number of genera, even in restricted groups, had not reached the specialization of today.

In the preparation of this paper, acknowledgment is due to the cheerful aid of Professor Stuart Weller, of the University of Chicago, and to the generosity of Curator F. C. Baker, of the Chicago Academy of Sciences, for the loan of specimens belonging to that institution.

CLASS *ARACHNOIDEA.*

ORDER *ANTHRACOMARTI.*

Family *Architarboidae* Karsch.

The genera of this family may be separated in the following manner:

Legs unusually long and slender: basal abdominal segments large: spinneretts present - - - - - - - - - **Kustarachne**

Legs thickened; basal ventral segments of the abdomen usually shortened; no spinning organs - - - - - - - - - - 2

2. Coxæ radiating from a triangular sternum - - **Anthracomartus**

Coxæ radiating from a median pit or ridge - - - - - - 3

3. Basal segments of abdomen strongly angulated; cephalothorax prominent, not markedly constricted from the abdomen - **Geraphrynus**

Basal segments nearly transverse, though often crowded - - 4

4. Cephalothorax narrower than the abdomen, or markedly constricted from it, suborbicular, the front more or less broadly angulate 5

Cephalothorax shorter than the abdomen, but not constricted from it, transversely orbicular, the front rounded - - **Architarbus**

5. Cephalothorax less than one-half as broad as the abdomen; legs short; large species - - - - - - - **Hadrachne** gen. nov.

Cephalothorax and abdomen of nearly equal breadth; legs comparatively long though stout; species less than one-half the size of the former - - - - - - - - - - **Geratarbus**

Hadrachne gen. nov.[1]

Stout-bodied; cephalothorax small, angulate anteriorly and transverse posteriorly, its sides nearly straight and more or less continuing the outline of the abdomen without a lateral con-

[1] ἀδρός, "stout;" ἀράχνη, "spider."

striction between the two. Post-thoracic plate broadly triangular, but not crowding the basal abdominal segments so that they become angulate. Abdomen greatly enlarged, regularly oval, broadest at the middle, consisting of nine segments. Legs short, coxæ wedge-shaped, radiating from a small central disc.

1. **Hadrachne horribilis**, sp. nov. (Plate V, Fig. 1; Plate VII, Fig. 1).

The cephalothorax is triangular in outline, bluntly pointed in front. Its texture shows no punctation nor other sculpturing. The sutures between the pedigerous segments are finely indicated and converge to a small elliptical, longitudinally disposed central space which may indicate a shallow depression or lie level with the surface. Unfortunately, as in its relatives, although the dorsal surface is exposed, no traces of eyes can be observed. The posterior plate of the thorax has its surface granular. As in its allies, it is crenulate, the ridges curving anteriorly. The post-thoracic shield overlying the base of the abdomen is broad and shallow, its posterior edge quite obtusely rounded, rather than angulate; its surface is impunctate. The six basal segments of the much-swollen abdomen occupy nearly one-half of the body, and are of nearly equal size. At the margin they are widest, and become narrower at the middle to accommodate the post-thoracic shield. The sixth segment is but slightly bowed. These segments are finely punctulate and possibly may have been smooth. The apical half of the abdomen, however, is decidedly granular, the granules becoming irregular, confused, and confluent apically. No anal tubercle is visible. The incisures of the segments do not interrupt the outline of the abdomen. The lateral sulcus extending longitudinally is evident. The legs are remarkably short and slender for so stout a creature. Palpi similar to the legs, equally stout, but somewhat longer. The coxæ consist of closely contiguous, distally expanded, wedge-shaped pieces, which meet about a small median inclosure. The remaining segments of the legs are individually stout, not over twice as long as broad.

Length of whole spider 39^{mm}, of cephalothorax 13^{mm}, of abdomen proper 20^{mm}; breadth of cephalothorax at base 14^{mm}, of abdomen at middle 23^{mm}; length of leg-joints 3.5^{mm}.

A single specimen represented by one-half of an ironstone nodule from Braidwood, Ill., collected by Mr. M. Fischer. This is by far the largest Anthracomart-spider yet discovered. The great size of the abdomen and the contrastingly small cephalothorax will readily distinguish it from the other genera of the order.

Type. Pal. Coll. No. 9232.

2. **Geraphrynus carbonarius** Scudder (Plate V, Fig. 3; Plate VII, Fig. 3). *Proc. Am. Ac. Arts Sc.* Vol. XX (1884), pp. 16, 17.

A beautifully preserved specimen of this common species, measuring 24^{mm}, exhibits nothing unnoticed in Dr. Scudder's lengthy description. The post-thoracic piece is triangular.

Pal. Coll. No. 9233.

3. **Architarbus rotundatus** Scudder (Plate V, Fig. 2; Plate VII, Fig. 2). *Geol. Surv. Ill.*, Vol. III (1868), p. 568, Fig. 4.

A well-preserved specimen, showing nearly the whole of the legs and the structure of the body, appears to belong to this species.

Pal. Coll. No. 9234.

4. **Kustarachne sulcata** sp. nov. (Plate V, Fig. 5; Plate VII, Fig. 4).

Cephalothorax orbicular, nearly as broad as the abdomen, from which it is evidently, though not deeply, constricted. Coxæ meeting along a narrow median space which extends along the whole length of the cephalothorax, stout, distinctly and deeply punctulate; remainder of legs punctulate also, more slender than the coxa, especially on the tarsal portion; metatarsus as long as the basal portion of the leg together. Mouth parts not distinct. Abdomen somewhat broader than the thorax, elongate elliptical, its segmentation obscured, irregularly but deeply punctulate, the punctures becoming obsolete in the middle, provided with a prominent lateral sulcus concentric with and close to the margin, and with a broader and deeper longitudinal one on the disc on each side of the middle. Abdomen terminated by a triangular sessile pygidium consisting of two and possibly three subsegments, its outline extending beyond the regular oval of the abdomen, not punctured. The basal appendages noticed in *tenuipes* are not indicated, but there is a

mark on the stone which might have been caused by a terminal seta. This is as fortuitous as in the other species, but its presence casts even darker gloom over the systematic position of the genus.

Length of body 15^{mm}, width of cephalothorax 6.5^{mm}, length of abdomen without the pygidium 9^{mm}, width of abdomen 7^{mm}, width of first subsegment 2^{mm}, length of second leg (imperfect) 24^{mm}, width of second leg beyond body 0.75–0.3^{mm}.

Carboniferous. Mazon creek, Illinois.

Type. Pal. Coll. No. 9235.

Although the imperfect type of this genus offers but few salient characters, the present form is placed congeneric with it in entire confidence. It concurs with the characters of no other Anthracomart, but agrees with *Kustarachne tenuipes* in its general form, slender, elongate, but somewhat stouter legs, and similar pygidium. However, it is quite distinct in the sculpture of the abdomen.

5. **Kustarachne exstincta** sp. nov. (Plate V, Fig. 4; Plate VII, Fig. 5).

A single specimen in fragmentary condition. Cephalothorax confused, apparently transversely rounded; the coxæ large and meeting about a deep central depression; the post-plate (if there be one) not indicated. Abdomen rounded oval, its segmentation rather distinct; seven and possibly eight segments indicated, of which the basal segments are longer than the apical, the diminution in size being gradual. The last three segments are outlined by an impressed line. At the termination of the abdomen is a triangular two-jointed pygidium with a prominent mammilliform spinnerett on each side of the last segment. At some distance beyond the body there is an indication of a slender setiform appendage, though whether this is a portion of the post-abdomen or a fragment of a tarsus cannot be ascertained. The latter view seems more likely the correct one, and would also explain the "post-abdomen" of the other species. The lateral sulcus is vague, but seems to be distant from the margin of the abdomen; this may be due to the crushed and contorted condition of the fossil. No median grooves or ridges: surface of the body minutely and densely punctulate, the punc-

tures much finer and denser than in *sulcata*. Legs vaguely indicated as scattered fragments. What remains shows them to have been excessively long and slender; the strong flexure at the coxal joints and the absence of the middle parts of the legs would indicate that the body was carried much as with the Phalangidæ of today.

Length of body 14^{mm}, length of abdomen 9^{mm}, breadth of abdomen (approximate) 7^{mm}, breadth of cephalothorax (approximate) 5^{mm}.

Mazon creek, Illinois. Carboniferous.

Type. Pal. Coll. No. 9236.

This genus possesses some of the characters of the Anthracomarti and some of the true spiders. The formation of the coxal plates is quite suggestive of the former order, while the peculiar segmentation of the abdomen—the basal segments being as large or larger than the apical—and the possession of what are possibly spinning organs are equally incongruous for the group. But two true spiders are known from Carboniferous times, both discovered in Europe. The best-known of these, *Protolycosa anthracophila* F. Roemer, has abdominal appendages and distinctly segmented abdomen. The other, *Palaranea borassifolia* Frič, is fragmentary, but seems to be devoid of these appendages. Even if the appendages at the end of its abdomen be interpreted as spinning organs, *Kustarachne* cannot be included with these, as its relationships are closer with the Anthracomarti, as can be seen by its sessile abdomen and the arrangement of its coxæ. It would seem as if this genus, of which the three species agree pretty closely, was in the line of descent from the ancestors of both the Anthracomarti and the Araneæ, related more closely to the former, but sufficiently removed to be considered now as equivalent to the other genera of the group together.

Although archaic, *Kustarachne* is not ancestral. Even at this early period it had attained a certain degree of specialization in the loss of its abdominal legs, the anchylosis of the basal segments of the abdomen, and the peculiar development of its legs. But that it was not so highly organized as its contemporaries

can be surmised from the imperfect fossil remains. Like many archaic or young types, its body-chitinization is not complete, and its frailer structure is represented but vaguely in the same rocks that bear such excellent witness of the rulership of the scorpion and the Anthracomart.

ORDER *SCORPIONES.*

Family *Eoscorpionidae* Scudder.

6. **Eoscorpius carbonarius** Meek and Worthen.
Geol. Surv. Ill. Vol. III, p. 560, text figure.

This specimen is the reverse of the one illustrated by Meek and Worthen, being the opposite portion of the same ferruginous concretion.

Cotype. Pal. Coll. No. 8949.

CLASS *INSECTA.*

DIVISION PALÆODICTYOPTERA Goldenberg.

SECTION ORTHOPTEROIDEA Scudder.

Family *Palaeoblattariae* Scudder.

7. **Mylacris Gurleyi** Scudder.
Bull. U. S. Geol. Surv., No. 124 (1895), p. 43, Plate I, Fig. 5.

Type. Pal. Coll. No. 6389.

8. **Mylacris Mansfieldi** Scudder.
Mem. Bost. Soc. Nat. Hist., Vol. III, p. 47, Plate 5, Fig. 15.

This is the specimen mentioned by Scudder as coming from Vermilion county, Ill., the original type of the species being from Cannelton, Pa.

Pal. Coll. No. 9237.

9. **Promylacris ovalis** Scudder.
Proc. Ac. Nat. Sci., Phila., 1885, pp. 34, 35.

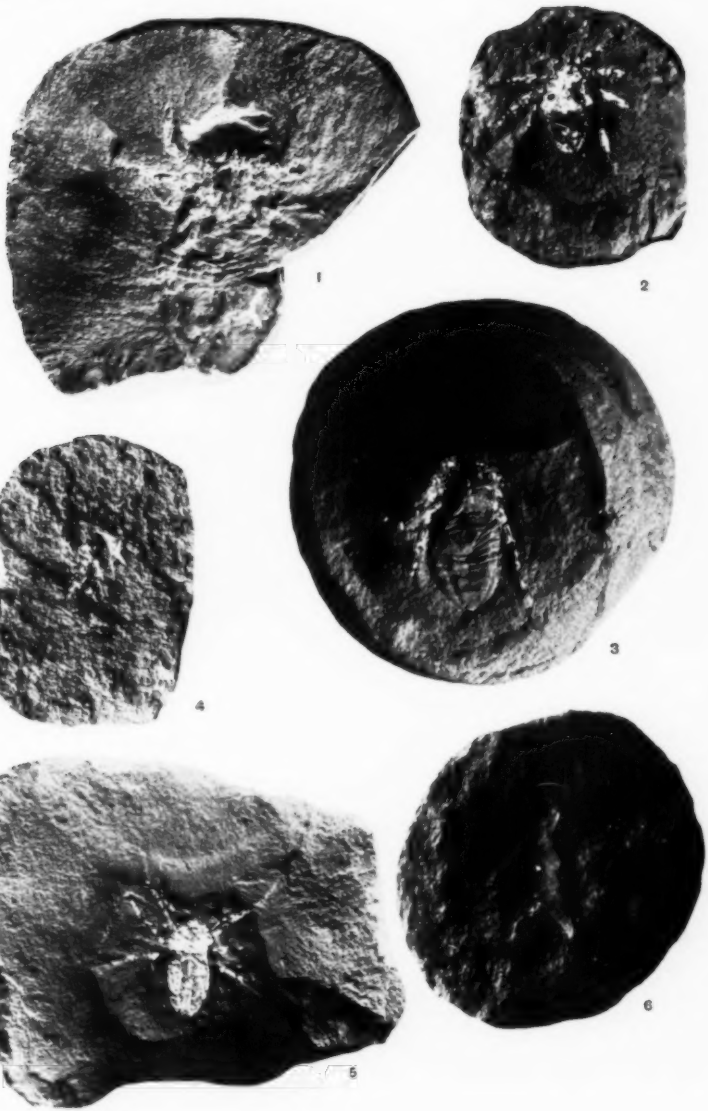
Type. Pal. Coll. No. 6387.

Another well-preserved specimen of slightly smaller size appears to belong with this species. It comes from the same locality and the same formation.

Pal. Coll. No. 9238.

10. **Lithomylacris simplex** Scudder.
Mem. Bost. Soc. Nat. Hist., Vol. III (1879), pp. 51, 52, Plate 5, Fig. 5.

Type. Pal. Coll. No. 6390.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11. **Mylacridae sp.**

Scudder, *Bull. U. S. Geol. Surv.*, No. 124, p. 55, Plate II, Fig. 4.

This is supposedly the humeral angle of the tegmen of a gigantic cockroach.

Figured specimen. Pal. Coll. No. 8948.

The collection contains a large and rather well-preserved specimen of *Dipeltis diplodiscus* Packard (*Am. Nat.* 1885, p. 293), measuring nineteen millimeters in length. The remarkable resemblance between this supposed Phyllopod crustacean and a nymph or wingless female of the cockroaches can be seen from the accompanying figures of the species. (Plate V, Fig. 6; Plate VII, Fig. 6.)[1]

Family *Protophasmidae* Brongniart.

12. **Paolia Gurleyi** Scudder (Plate VII, Fig. 7).

Proc. Am. Acad. Arts Sc., Vol. XX, p. 173.

This interesting specimen, found in a whetstone from French Lick, Orange county, Ind., is here figured for the first time.

Type. Pal. Coll. No. 6393.

13. **Dictyoneura clarinervis** sp. nov. (Plate VI, Fig. 1; Plate VII, Fig. 8).

Wing. Length 33^{mm}; greatest breadth, at middle, 10^{mm}; rather pointed. Humeral angle explanate, filled with very oblique cross-veins from the mediastinal vein; mediastinal oblique and vanishing at the end of the middle third of the wing. Scapular vein parallel with and not distant from the mediastinal, ending in the costa about one-seventeenth the distance from the tip at a slight indentation marking the termination of the marginal vein; near its extreme base the scapular vein emits a lower branch unevenly divaricating from the main stem and furcating just before the last third, the lower branch trifurcating toward the tip and ending at the wing-apex. Externomedian vein not well indicated at the base, owing to the plication of the wing; it furcates once near the point of branching of the lower scapular vein and possibly is split near the tip. Internomedian vein simple, sharply delineated. Anal vein extremely prominent, filling nearly the whole of the hind half of the wing, emitting

[1] In a paper just issued E. H. SELLARDS assigns this species to *Mylacris* (*Am. Jour. Sc.*, April, 1903, p. 309). The shape of the pronotom agrees very well with *Promylacris rigida* Scudd.

four downward offshoots within the wing-area, of which the first and fourth are basally furcate, and one from the anal angle. All the veins are connected by rather distant cross-veins or scrobiculi, which are strongly oblique, though in a sense opposite to those anterior to the mediastinal.

Found in an ironstone nodule six miles southeast of Danville, Ill., at Grape creek, by Mr. W. F. E. Gurley.

Type. Pal. Coll. No. 9240.

This species, while clearly belonging to the genus *Dictyoneura* in the restricted sense of Scudder, not of Brongniart, is markedly distinct from its congeners in the great development of the anal vein. This vein has over twice as many branches as in any of the other species. This is the first American form, all the others being European from the Saarbruck basin.

SECTION NEUROPTEROIDEA Scudder.

Family *Homothetidae* Scudder.

14. **Didymophleps contusa** Scudder.

Mem. Boston Soc. Nat. Hist., Vol. III, pp. 330, 331, Plate 29, Fig. 6.

Type. Pal. Coll. No. 6392.

15. **Cheliphlebia extensa** sp. nov. (Plate VI, Fig. 2; Plate VII, Fig. 9).

Body elongate, slender, subcylindrical, of moderate size. Head narrow, comparatively small. Prothorax narrow and prolonged. Legs rather robust. Wings large, overlapping on the abdomen, broadest at the beginning of the outer fourth; costal margin nearly straight; apex of wing broadly rounded; mediastinal vein very short; scapular vein long, extending to near the tip of the wing, parallel with the costa, connected with the marginal by a series of moderately close, oblique, curved, simple cross-veins. Externomedian vein first forked at the middle of the wing; its lower stem simple, its upper again forked, and each branch again dichotomizing, the upper twice, the lower once. Internomedian vein emitting a number of gently curved, rather distant, oblique branches from its lower side, parallel with those of the externomedian, and filling the hinder portion of the wing. Cross-veins feeble or possibly wanting altogether, except those on either side of the scapular vein.

Head subquadrate, small, slightly longer than broad, and

somewhat broader in front of the eyes, its sides otherwise nearly parallel; posterior angles rectangular, but little rounded; mandibles triangular, short, though strong, much curved on their outer border, pointed; eyes prominent, elongate, narrowly extending along the sides of the head. Head with a broad median longitudinal carina. Antennæ slender, setiform. Prothorax slender, nearly twice as long as the head, divided at the middle by a transverse sulcus. The anterior part of the prothorax is of slightly less breadth than the posterior, its front edge straight. Front coxæ comparatively small, attached to the sternum just behind the transverse sulcus, not contiguous on the median line; remainder of the front legs vague. The indications show them to be short and robust. Mesothorax as long as the head, slightly broader than long, quadrate, simple; the middle legs are attached at the posterior part of this segment, and also are vaguely defined. Metathorax of equal length with the mesothorax, but of gradually increasing breadth, its hind edge circularly excised for the intermediary segment; hind coxæ large, prominent, globoso-quadrate, marked with fine longitudinal striæ, hind femora but twice the length of the coxæ, apparently much compressed, marked with longitudinal furrows on the sides and more or less sulcate for the reception of the slender, outwardly bowed tibiæ; tarsi long and slender, the last joint expanding, elongate obcordiform; claws and empodium visible, one-half the length of the last tarsal joint. Abdomen subcylindrical, slender, slightly longer than the head and thorax together, consisting of eleven segments, including the intermediary segment, gradually tapering to the middle (sixth segment), then suddenly narrowed on the next two segments, thence subparallel to the tip. Anal cerci visible, apparently about one-half the length of one of the segments of the abdomen. Wings long, overlapping over the abdomen, two and one-half times as long as broad, veins fine; costal margin nearly straight, especially on the middle third of the wing; anal margin vaguely defined; apex of wings apparently rounded. Mediastinal vein short, not appearing in the faint basal impression of the wing; scapular vein nearly conforming with the costal curvature, meeting the margin at the outermost eighth of the wing,

and connected with the faint marginal vein by a series of about eighteen oblique, curved, simple cross-veins; externomedian vein separated from the scapular by a rather broad interval, its five or six branches filling out the apex of the wing; internomedian vein feeding the greater part of the hind margin with equidistant simple branches; anal veins numerous, straight, simple, indicating a rather full anal area. Hind wings apparently of the same structure as the fore ones, and of nearly the same extent. The venation is obscured.

Length of body from base of mandibles to end of last abdominal segment 41^{mm}, mandible 0.7^{mm}, head 3.7^{mm}, prothorax 8.3^{mm}, mesothorax 5^{mm}, metathorax 3.5^{mm}, abdomen 21^{mm}, anal cercus 1.2^{mm}, hind coxa 3^{mm}, hind femur 6.8^{mm}, hind tibia 5.5^{mm}, hind tarsus 5.5^{mm}, front wing 32^{mm}, hind wing 26^{mm}, breadth of head 3^{mm}, prothorax 3.5^{mm}, mesothorax 6^{mm}, metathorax 6.7^{mm}, sixth abdominal segment 5.5^{mm}, eighth abdominal segment 3^{mm}, wing at widest part 12^{mm}.

Carboniferous. It was found as an opened iron-stone nodule at Mazon creek, Illinois, only one-half of the concretion being obtained. It represents the dorsal aspect of the insect, and is partially water-worn.

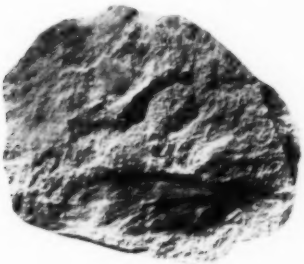
This species seems to have its nearest relative in *Cheliphlebia elongata* Scudder, from the same formation, conforming best with the venation of that species. However, the present form differs in the brevity of the mediastinal vein, the narrow scapular area, and the course of the externomedian vein.

The hind legs are stouter than usual for a neuropteroid insect, with ridges and sulci reminding one somewhat of the sculpture of an orthopterous leg. The swelling of the central part of the abdomen would indicate that the specimen is a female with the basal half of the abdomen distended with ripened ova. The prominence of the tenth abdominal segment shows that the abdomen was carried with a dorsal hump and with the tip directed ventrally, somewhat in the manner of living female Embiidæ of today.

Type. Pal. Coll. No. 9241.

16. **Eucaenus mazonus** sp. nov. (Plate VI, Fig. 3; Plate VII, Fig. 10).

Broad-winged species; prothorax longer than broad, meso-



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and metathorax quadrate. Abdomen elongate-ovate, no median keel present. Wings very broad. Legs short, moderately strong, punctulate.

Head ovate, about two-thirds as long as the prothorax, rounded on the posterior angles; eyes bulging, hemispherical, not large; mouth-parts not defined. Prothorax broadly ovoid, rounded behind, straight in front; meso- and metathorax gradually broader posteriorly, their side angles rectangular. Abdomen broad, elongate-oval, more or less depressed, consisting of ten segments, including the segment mediaire, broadest at the sixth segment, and then gradually and broadly rounded to the tip; only the base of the anal stylets visible; last segments not carinate. Legs short, femora stout, compressed; femora and tibiæ minutely and closely punctulate: on the forward side of each femur is a longitudinal boss near the inferior edge. Wings very broad, longer than the abdomen; the costal margin evenly rounded, except at the axillary angle of the hind wings, where it is strongly shouldered; mediastinal vein straight, oblique, distant from the marginal at its base and connected with it by numerous oblique, straight cross-veins; scapular vein close to the mediastinal, the other veins obliterated. Under wings with numerous branches to the externomedian.

Length of body 24^{mm}, of prothorax 4.5^{mm}, of mesothorax 3^{mm}, of metathorax 3.4^{mm}, of abdomen 10^{mm}, of fore wing 20^{mm}, of front femur 3.3^{mm}, of hind femur 6.3^{mm}, of hind tibia 3.5^{mm}. Breadth of prothorax 3^{mm}, of mesothorax 3.8^{mm}, of metathorax 4.7^{mm}, of sixth abdominal segment 5.5^{mm}, of front wing 8^{mm}.

Described from a specimen represented on both sides of an ironstone nodule from the Carboniferous beds at Mazon creek, Illinois.

This species seems certainly to be congeneric with *ovalis* Scudder, and may possibly be the same form. In some respects the state of preservation is better than that of Dr. Scudder's specimen, portions of the head and legs being visible, but the neuration is more obliterated. The shape of the prothorax and of the wings will distinguish this species from *ovalis*. The outline of the body is suggestive of a rather large Reduviid bug, with broad wings, rather than of a neuropteroid insect.

Type. Pal. Coll. No. 9242.

In the collection is another specimen (No. 9246) exhibiting the base of the head, the meso- and metathorax, and the base of the abdomen, together with a portion of the wings. The insect is of the same size as the specimen previously described, and appears to belong to the same species. Nothing further can be supplied to the diagnosis by the characters exhibited by this fossil. In its broadened wings the straight mediastinal and scapular veins alone are clearly cut, the other veins being indefinitely preserved.

17. **Eucaenus attenuatus** sp. nov. (Plate VI, Fig. 4; Plate VII, Fig. 11).

Head indefinite, but with a median carina; prothorax more or less quadrate, its sides nearly parallel; mesothorax transversely quadrate, much broader than long; metathorax and abdomen indefinite, but stout, ovate-pointed caudally; abdomen with nine uniform segments, the apical small, the last two segments with a sharp median keel. Legs compressed, rather short and stout, minutely punctate, the hind tarsi longer than the tibiæ. Wings large, not abrupt at the humeral angle, uniformly elongate-oval; mediastinal vein nearly straight, oblique, meeting the costa at the outer three-fourths, provided with numerous oblique cross-veins to the margin; scapular vein close to the mediastinal, parallel with it, and slightly curved so that the wing-margin and the scapular vein outline an elongate spindle-shaped area; the remaining veins obliterated.

Length about 28 mm, length of wing about 25 mm, breadth of wing 9 mm.

One specimen, an ironstone concretion from the Egan collection of the Chicago Academy of Sciences, No. 4749. Mazon creek.

The three species of this genus show the following interrelationship:

Last abdominal segments provided with a median keel - - - - 2
Last abdominal segments not carinate, costa and scapular vein opposedly curved - - - - - - - - - - - *attenuatus* sp. nov.

2. Scapular vein curved in an opposite sense to the costal margin *mazonus* sp. nov.
Scapular vein subparallel with the margin - - *ovalis* Scudder

Petromartus gen. nov.[1]

Head small, with prominent mandibles. Prothorax elongate; meso- and metathorax quadrate. Abdomen stout, tapering beyond the middle and provided with prominent sexual organs on the antepenultimate ventral segment. Legs rather stout. Wings long, exceedingly slender, rather triangular in outline, broadest at the beginning of the outermost third where the hind margin forms an obtuse angle; neuration simple, nearly straight; mediastinal vein long; scapular simple, unbranched. Externomedian several times branched; internomedian of similar formation. All the veins extend straight from the narrow base and evenly fill out the apical portion of the wing with a gentle curvature. Numerous well-marked and distant transverse cross-veins connect the longitudinal veins. Underwings similar, but probably broader. Wings overlapping the abdomen when at rest.

18. **Petromartus indistinctus** sp. nov. (Plate VI, Fig. 6; Plate VII, Figs. 12, 13).

Male.—Elongate slender insect with thickened abdomen, and very narrow fore wings. Head quadrate, longer than broad; mandibles prominent. Prothorax slender, elongate, provided with a transverse sulcus in front of the middle; sides and posterior edge margined. Mesothorax broader, rectangular, bearing the fore wings at the hind angles. Remainder of thorax and base of abdomen obscured. Abdomen broad, elongate, consisting of ten segments, including the mediary segment, which is supposedly present. At the eighth segment is a large and broad ventral tubercle bearing a pair of clasping valves which meet in a mid-longitudinal line. The sexual apparatus of the last segments and the caudal appendages are obliterated. Legs imperfectly preserved; femora compressed, their sides flat, twisted in position as described for the other species. Front wings more slender than the hind ones and comparatively smaller; veins straight, connected by numerous strong cross-veins; venation reconstructed as follows: mediastinal vein extending two-thirds to the wing-tip; scapular vein straight, parallel with the mediastinal, and connected with it by numerous transverse veins. These cross-

[1] *πέτρος*, "a stone;" *μάρτυς*, "a witness."

veins, while angular at the scapular vein, are prolonged to meet the rather distant main branch of the externomedian. The externomedian vein arises close to the scapular and continues parallel with it to the middle of the wing, when it is deflected downward so as to terminate at a distance from the scapular and at the tip of the wing. At the point of flexure it sends off a simple underbranch. Internomedian and anal veins confused, probably simply furcate and nearly parallel with the straightened and uninflated hinder margin. The under wings are broader and comparatively fuller than the upper, neuration probably nearly similar, but the veins less crowded basally.

Length 47^{mm}, length of head 5^{mm}, of mandible 1.25^{mm}, of prothorax 6^{mm}, mesothorax 4.5^{mm}, metathorax 4.5^{mm}, abdomen 27^{mm}, front wing 40^{mm}. Breadth of head 3^{mm}, of prothorax 3.5^{mm}, mesothorax 5.5^{mm}, metathorax 9^{mm}, fourth abdominal segment 7^{mm}, eighth abdominal segment 6^{mm}, front wing 8^{mm}. These measurements are approximate.

Both halves of an ironstone nodule discovered by Mr. William F. E. Gurley at Petty's Ford, Little Vermillion river, fourteen miles southeast of Danville, Ill. This is the same locality where *Termes contusus* Scudder and *Propteticus infernus* Scudder were found.

The metapleuræ have burst apart from the notum in the specimen, so that the hind wings are torn from their normal position. Thus above the abdomen four thicknesses of the wings are superimposed. From the narrowness of the fore wings we might surmise that these early insects were not powerful flyers, but flitted much as the damsel-flies or stone-flies do today.

Judged by the shape of the wings, with their strong distant cross-nervures, this form would be located near the genera *Woodwardia* and *Sphecoptera* of Brongniart, and placed in his family Megasecopterida. However, as this family coincides more or less with Scudder's Hemeristina, which is defined in more specific terms, it appears that the new form would be incongruous with its fellows. The elongate prothorax, the outline of the abdomen, and the course of the longitudinal veins more nearly correspond with the family Homothetidæ Scudder.

Its position in this group may be seen by the table given herewith. At any rate, we find here another link connecting the European fauna with that of America.

Type. Pal. Coll. No. 9243.

The relationships between the insects of this family can be quickly seen from the following conspectus arranged from the descriptions of the genera:

Mediastinal vein terminating before the middle of the wing - **Cheliphlebia**
Mediastinal vein extending beyond the middle of the wing - - 2
2. Mediastinal vein extending parallel with the marginal - - - 3
Mediastinal extending obliquely to the marginal - - - 5
3. Wings excessively narrow, provided with strong and distant cross-veins - - - - - - - - **Petromartus** gen. nov.
Wings less narrow, cross-veins less evident - - - - - 4
4. All the veins up to the internomedian parallel with the straight margin; branches of the internomedian oblique, parallel - **Didymophleps**
Veins more irregular; scapular branched near the tip - **Acridites**
5. Costal margin nearly straight - - - - - - - - 6
Costal margin bowed outwardly - - - - - - - - 7
6. Mediastinal without oblique branches, scarcely shorter than the scapular - - - - - - - - - **Homothetus**
Mediastinal with branches, extending two-thirds the length of the wing; scapular reaching nearly to the tip; cross-veins wanting **Anthracothremma**
7. Branches of the mediastinal and scapular veins crowded, similar **Eucaenus**
Branches of these veins dissimilar, uncrowded - - - - 8
8. Front wings obovate; branches of mediastinal simple, rather distant **Gerapompus**
Front wings less markedly ovate; some of the branches of the mediastinal forked - - - - - - - - - 9
9. Internomedian vein with numerous branches like those of the externomedian - - - - - - - - - **Genopteryx**
Externomedian vein far separated from the scapular, its branches more important than those of the internomedian - **Genentomum**

Family *Palaeopterina* Scudder.

19. **Dieconeura maxima** sp. nov. (Plate VI, Fig. 5; Plate VII, Figs. 14–16).

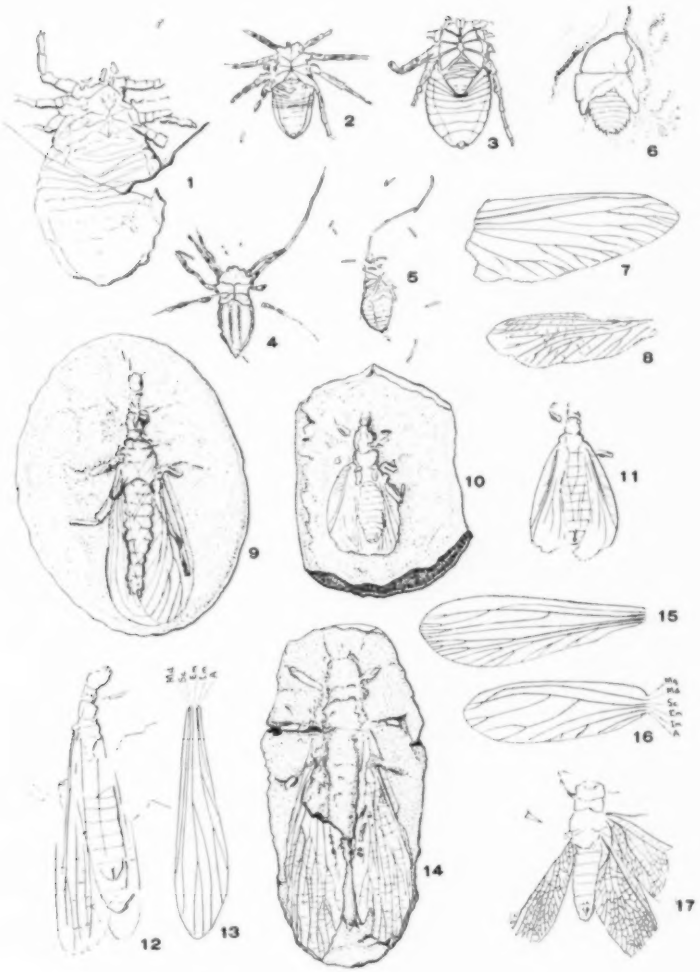
Large, elongate. Wings long, narrow, broadest at the beginning of the outermost fourth, costa nearly straight; of the fore wings the mediastinal vein is parallel with and close to the marginal, ending in the scapular somewhat beyond the middle of

the wing; scapular vein forked before the middle of the wing, the upper branch parallel with the costal margin, emitting a simple under branch, the lower branch simple or simply forked, nearly straight, rather distant from the upper and apically parallel with it. Externomedian vein simple, terminating near the tip of the wing. Internomedian forked at the middle of the wing, each branch simply forked near the tip. The main stem of the anal vein is more or less parallel with the hind margin, terminates in the margin at the beginning of the apical sixth of the wing, and sends a number of lower branches to the hind margin, which are simple or simply forked. Neuration of the hind wings nearly similar; the mediastinal is strong and deeply set in the explanate costal portion; scapular vein more important than in the fore wings, the divarication of its principal branches occupying a large part of the wing and filling the apical portion; remaining veins much reduced. Both wings filled with numerous cross-veins.

Body indefinitely preserved, but indicating a slender, *Corydalis*-like insect. Prothorax rounded in front, its sides parallel behind; mesothorax broader, quadrate; metathorax and abdomen vague, their segmentation scarcely visible. Wings surpassing the abdomen, their hind margins touching above the abdomen, but the wings do not overlap. Neuration of both pairs well preserved in large part. The femora of all the legs are in part indicated, and show that they were provided with prominent longitudinal ridges.

Length about 62^{mm}, length of thorax (pro-) 8, (meso-) 7, and (meta-) 7^{mm}, length of abdomen 31^{mm}, length of front wings 45^{mm}, breadth of front wings 15^{mm}.

The assignment of this species to the genus *Dieconeura* is quite permissible on account of the similarity between the wing-neuration of the different species. But it must be remembered that the new form is considerably the largest that has been placed here. The dissimilarity between the two pairs of wings, which is shown in the somewhat diagrammatic reconstruction, is rather striking for an insect of pre-Tertiary times. The interpretation of the neuration is quite likely the correct one, as large portions of the veins of both wings are well indicated on the fossil.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The three species just described show a marked agreement in the resting position of the hind legs. In each case the femur is twisted in such a manner that the tibia is directed forward and away from the body. This primitive attitude is retained by a few insects of today, such as stone-flies, earwigs, the Embiidæ, *Gryllotalpa*, etc., and by the nymphs of many neuropterous insects.

Carboniferous, Mazon creek.

Type. Pal. Coll. No. 9244.

20. **Propteticus infernus** Scudder.

Mem. Boston Soc. Nat. Hist., Vol. III, pp. 334–6, Plate XXXI, Figs. 3, 4.

Type. Pal. Coll. No. 6391.

The following dichotomy will serve to assist in the assignment of the genera of this group:

Internomedian vein ending in the middle of the lower margin, with numerous branches arising from its upper side - - - - **Strephocladus**

Branches of internomedian springing from below; if from above not ending in the hind margin - - - - - - - - - - - - - 2

2. Internomedian with an adventitious vein running across the externomedian into the scapular - - - - - - **Aethophlebia**

Internomedian of regular formation - - - - - - - - 3

3. Externomedian unforked, following the course of the internomedian **Dieconeura**

Externomedian forked - - - - - - - - - - - - 4

4. Scapular vein close to the mediastinal, straight, its principal branch arising near the middle of the wing and nowhere far removed from the stem - - - - - - - - - - - **Miamia**

Scapular vein bent, separated from both the mediastinal and its principal branch - - - - - - - - - - **Propteticus**

Family *Hemeristina* Scudder.

Protodictyon gen. nov.[1]

Body short, very robust. Pro-, meso-, and metathorax quadrate, broad. Abdomen robust, the last segments provided with a median keel. Wings, large, broad, mediastinal vein ending in the costa beyond the middle; scapular vein strong, parallel with the mediastinal, emitting a distant under-branch near the base of the wing, which dichotomizes several times in an irregular manner. Externomedian vein contiguous with the scapular stem on its basal portion and then suddenly deflected.

[1] *πρῶτος*, "earliest;" *δίκτυον* "net."

It also dichotomizes irregularly and often. Internomedian and anal veins much reduced. Cross-veins numerous, forming a more or less complete reticulation.

21. **Protodictyon pulchripenne** sp. nov. (Plate VI, Fig. 7; Plate VII, Fig. 17).

Head not indicated. Prothorax large, square, the sides biarcuately sinuate, meso- and metathorax transversely quadrate, narrower than the prothorax; abdomen robust, nine segments visible, the eighth and ninth with a short median keel. Beyond the abdomen are well-preserved indications of two long setiform appendages. Legs vaguely represented, but apparently quite long. The beauty of this specimen, however, lies in the excellent preservation of the wing-neuration, which is clearer cut than in any fossil of its kind yet discovered. Every vein, branch, and cross-nervure is as clearly depicted as in the living insect. Wings full, large as compared with the length of the insect, costal margin nearly straight: mediastinal, scapular, internomedian, and anal areas much reduced; externomedian and scapular veins prominent, occupying the larger part of the wing; mediastinal vein subparallel with the margin, ending in it considerably beyond the middle of the wing. Main scapular stem nearly straight, prominent, gradually converging with the margin and ending three cross-veins beyond the tip of the mediastinal; near the basal fifth the scapular sends down a widely diverging branch, which then continues toward the wing tip, anastomosing in numeroug zig-zag branches with the cross-veins. The externomedian vein is likewise strong, lying contiguous with the scapular branch on its basal portion. Two-thirds of the way toward the scapular branch it suddenly is deflected downward and branches at this point; both branches furcate repeatedly, the lower also connected with the hind margin of the wing by several off-shoots. Internomedian and anal veins poorly developed, occupying the much-reduced anal angle. All the veins connected by rather distant, more or less irregularly disposed cross-veins, which form a conspicuous reticulum with the broken nervures. Fore and hind wings nearly similar, the hind ones slightly broader.

Length without head 25^{mm}, size of wing about 40^{mm} by 10^{mm}.

One specimen, represented by the obverse and its reverse. Mazon creek, Ill., Carboniferous. From the Egan collection of the Chicago Academy of Sciences, No. 4749.

This is by far the best specimen of the ironstone fossils, the insect being preserved with the wings of the right side extended and not overlapping; the neuration is perfect.

Inasmuch as Dr. Scudder states that the figure of *Chrestotes lapidea* is erroneous in part, and elsewhere characterizes the genus as having the scapular vein and its main branch approximated, we shall have to regard the present specimen as excluded from this genus. With *Hemeristia* it therefore agrees in this character, and in the disposition of the main veins, but here the veins are straight and simply connected by transverse cross-veins, and exhibit no trace of reticulation. Thus the present genus is characterized briefly by the angular course of the veins and the prominent reticulation of the cross-veins.

Family *Gerarina* Scudder.

22. **Gerarus danae** Scudder.

Geol. Surv. Ill., Vol. III, p. 566, Fig. 1.

There is in the university collection what we have reason to believe is the type of this species, inasmuch as the strange outline of the body together with the general neuration is as depicted in the figure. However, the shape of the rather large and rounded stone is quite different from that in Dr. Scudder's illustrations. Should this be the type, a slight error has been committed in figuring the termination of the mediastical vein. Toward the tip, this becomes irregular, owing to its flexture at each cross-vein. This might lead one, especially in a poorly preserved specimen, to suppose that the mediastinal terminates in the scapular vein, or, as in *Xenoneura antiquorum* Scudder or *Dictyoneura libelluloides* Gold., that it ends in a cross-vein rectangularly bent, its upper half somewhat the longer. However, in such a case the great length of the mediastinal vein, together with the numerous under-branches of the scapular, would easily lead one to recognize its affinities with this family.

Type. Pal. Coll. No. 9245.

In addition to the twenty-three species here enumerated there

is still another specimen exhibiting a wing shaped like that of *Paralogus æschnoides* Scudder, but of which the neuration is obscured.

EXPLANATION OF THE PLATES.[1]

PLATE V.

FIG. 1. *Hadrachne horribilis*, g. et sp. n.
FIG. 2. *Architarbus rotundatus* Scudd.
FIG. 3. *Geraphrynus carbonarius* Scudd.
FIG. 4. *Kustarachne sulcata*, sp. n.
FIG. 5. *Kustarachne exstincta*, sp. n.
FIG. 6. *Dipeltis diplodiscus* Pack.

PLATE VI.

FIG. 1. *Dictyoneura clarinervis*, sp. n.
FIG. 2. *Cheliphlebia extensa*, sp. n.
FIG. 3. *Eucænus mazonus*, sp. n.
FIG. 4. *Eucænus attenuatus*, sp. n.
FIG. 5. *Dieconeura maxima*, sp. n.
FIG. 6. *Petromartus indistinctus*, g. et sp. n.
FIG. 7. *Protodictyon pulchripenne*, g. et sp. n.

PLATE VII.

FIG. 1. *Hadrachne horribilis*, g. et sp. n.
FIG. 2. *Architarbus rotundatus* Scudd.
FIG. 3. *Geraphrynus carbonarius* Scudd.
FIG. 4. *Kustarachne sulcata*, sp. n.
FIG. 5. *Kustarachne exstincta*, sp. n.
FIG. 6. *Dipeltis diplodiscus* Pack.
FIG. 7. *Paolia gurleyi* Scudd.
FIG. 8. *Dictyoneura clarinervis*, sp. n.
FIG. 9. *Cheliphlebia extensa*, sp. n.
FIG. 10. *Eucænus mazonus*, sp. n.
FIG. 11. *Eucænus attenuatus*, sp. n.
FIG. 12. *Petromartus indistinctus*, g. et sp. n.
FIG. 13. *Petromartus indistinctus*, restoration of fore wing. *Md*, mediastinal; *Sc*, scapular; *Em*, externomedian; *Im*, internomedian; *A*, anal.
FIG. 14. *Dieconeura maxima*, sp. n.
FIG. 15. *Dieconeura maxima*, fore wing restored.
FIG. 16. *Dieconeura maxima*, hind wing restored. *Mg*, marginal vein; other letters as in Fig. 13.
FIG. 17. *Protodictyon pulchripenne*, g. et sp. n.

AXEL LEONARD MELANDER.

[1] All figures are natural size.

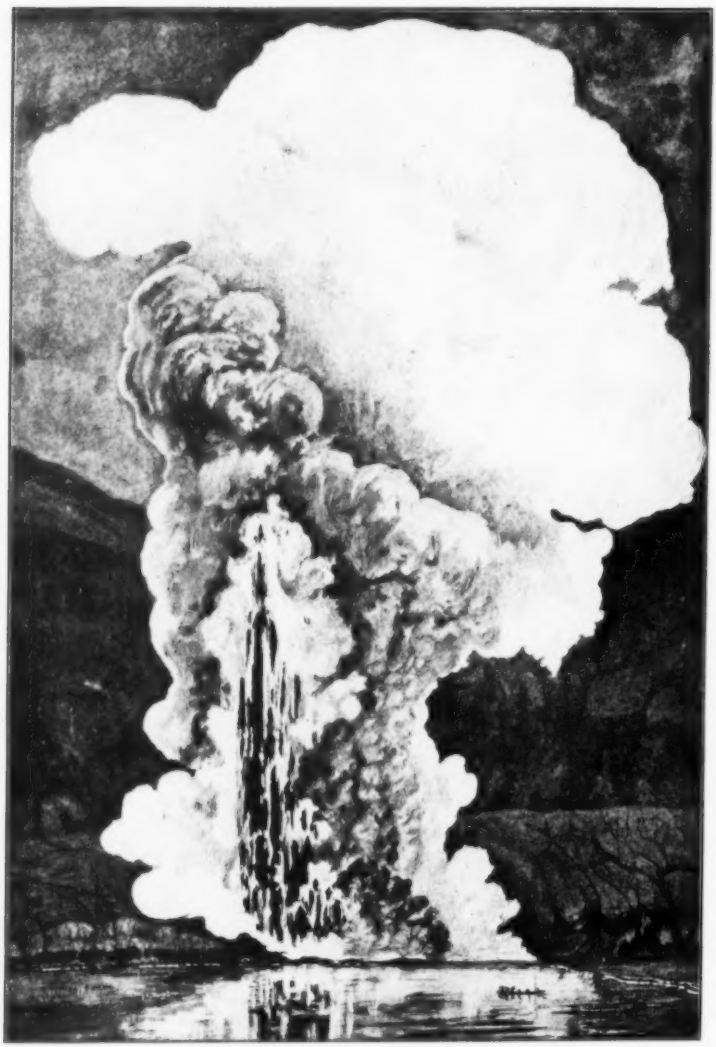
SECONDARY PHENOMENA OF THE WEST INDIAN VOLCANIC ERUPTIONS OF 1902.[1]

A COMPLETE report on the secondary volcanic phenomena of the West Indian eruptions of 1902 should include at least the following topics:

Development of consequent streams upon an initial ash surface.
Stream deflections by volcanic ejecta.
Subsidence of coastal plain.
Elevation of marginal deposits.
Effect of "tidal" or reflex waves.
Results of marine erosion.
Sedimentation of sea deposits.
Eruption within stream valleys.

The latter subject has been selected for this paper, leaving the others for later publication. According to some views I should include also as secondary phenomena the earthy flows of detrital matter which have played an important part in the destruction both of life and property, and have been generally reported as "mud flows." I regard them as, in part at least, of primary volcanic origin and think that the "mud flow" which buried the Guerin sugar works on May 5 — two days before the destruction of St. Pierre — was a result of an eruption from the crater of Mount Pelée. After the great eruption of May 7 on St. Vincent, more than half a billion gallons of water had disappeared from the crater lake of La Soufrière, which we found, on reaching the crater's rim on May 31, to have fallen about 800 feet below its former level. The evidence indicates that this volume of water was poured out over the mountain, bearing with it bowlders and "earth." This "earth" was composed of soil washed from slopes, the finer fragments of volcanic ejecta, and comminuted rock which has been commonly referred to as "ash." Mingled with widely varying percentages of water, the mixture was generally termed "mud," and in many instances "lava." In the May 6

[1] Paper read before the American Association for the Advancement of Science, January 2, 1902.



By permission of the "Century Co."

FIG. 1.—Outburst of dust-laden steam at the mouth of the Wallibou river, St. Vincent.

issue of *Les Colonies* (the last save one of this St. Pierre journal), under the headings "La catastrophe de l'Usine Guérin," the "flow" is described as "le débordement de lave." About noon on May 6 — the day before the memorable eruption — the inhabitants of St. Vincent, on both leeward and windward sides of the volcanic cone, saw the paths of the principal rivers flooded with "mountains of steaming waters." On June 24 I saw from its banks the catastrophic rush of earth, and bowlders, and water which plowed through the channel of the Sèche river. This flow took place during one of the heaviest of the minor eruptions of Mount Pelée, which, however, had been preceded by four

FIG. 2.—The Terre Fendue; or outlet to Pelée crater (eruption cloud obscures inner fragmental cone). Taken from the highest spurr of the "St. Pierre" ridge, which trends across the head of the Blanche river, by C. C. Curtis on June 26, 1902.

hours of very heavy rain. Two days later I reached the spur of the "St. Pierre ridge" which trends across the "Terre Fendue," or lip of Pelée's crater. It was possible from this position to see directly into the crater. During a minor outbreak, the channel of the gorge began to send out vapor, while its water both visibly and audibly increased. This I interpreted as erupted water. On May 8, according to M. Déseré, mayor's deputy at Grande Rivière, at 4 A. M.—four hours before the destruction of St. Pierre—a great flood, bearing bowlders up to six feet or more in diameter, came rushing down and buried the lower part of the town some twelve feet, where the stream formerly debouched into the sea. There had been little rain before this flood. Similar floods took place at this village of Grande Rivière on May 11, on June 6—the day of perhaps the heaviest eruption of Pelée on record—and on June 22 (when I was about two miles off the delta of the Grande Rivière, in a sloop, though unaware of such occurrence). Little rain fell on this day. The towns to the southward, situated at the mouths of streams heading on Mount Pelée, were visited by similar catastrophes.

From these accounts it appears that the major eruptions have been accompanied or preceded by "mud flows," and evidence indicates that the waters of the crater lakes have been discharged over the mountain sides. If fragmental material has accompanied these ejections of water, as it has the other eruptions, it is reasonable to assume that much of it would have been carried down into the lower valleys. The fine dust which was observed to be accumulating within the crater of Pelée would be swept down during such a flood, together with much of the fragmental material lying upon the inner cone. Re-ejected material, both coarse and fine, which had fallen within the crater might be either washed down the inner cone and out through the lip, or in a stronger outburst deluged over the upper slopes of the outer cone to be distributed by the summit-heading valleys. Dr. E. O. Hovey has reported these "mud flows" as due to landslides.[1] While this may account possibly for some of the minor occurrences, it can explain with difficulty the great volume of water necessary to convert the

[1] *Bull. Am. Mus. Nat. Hist.*, Vol. XVI.

unconsolidated cover over the bed-rock into a liquid-like torrent moving with great rapidity, and maintaining this state for several miles from its assumed source, especially since the remarkably porous quality of the "ash" cover renders it a very poor water-bearing medium. Some of the small, viscous-flowing mud streams originated in the cutting down of landslide dams behind which stream water had accumulated, as we observed on St. Vincent, but it is difficult to conceive how in the narrow, steep, graded canyons, large bodies of water could be collected sufficient to have caused the greater flows. Drs. Anderson and Flett[1] state that the "crater lake of La Soufrière was probably driven down over the lip of the crater and poured

FIG. 3.—Delta of the Grande Rivière. Showing character of flood deposit which destroyed lower portion of the town. Natives standing along former shore line.

[1] *Proc. Royal Soc.*, Vol. XX, p. 426.

down the valleys into the sea." The transporting power of such a flood is tremendous. Professor Angelo Heilprin says of the flood of May 5:[1]

"Hardly had the mid-day hour passed when the gates of the volcano were drawn, and a flood of boiling mud was sent hurling down the mountain side to be flung from it into the sea. In three minutes it had covered its three miles to the ocean. . . . . It is needless to ask whence came the mud; it could plainly be traced to the position of the Soufrière or Étang Sec."

Dr. T. A. Jaggar writes:[2]

This crater [Pelée] ends in a deep gulch west that extends down to the sea. . . . . Apparently it was down this gulch that the mud flood came which overwhelmed the Guérin factory.

M. Parel, Vicar General of Martinique, in his memorable record of the beginning of the disturbances on Mount Pelée,[3] states:

Since the morning [May 5] Rivière Blanche, which for some days had been swelling to disquieting proportions, although there had been no rain, had assumed suddenly the aspect of a menacing and muddy torrent. . . . . At the same time a moving column of vapor was seen in the high valley (see Fig. 2) that extends from the crater. . . . . It was an avalanche of black mud, ejected by the crater, and swollen by successive discharges until it became a rolling mountain, while it was breaking its way through the deep gorge. The moment it approached the delta, its presence was betrayed by the ascending vapors.

This show of vapors indicates the presence of some steam-generating factor, which was probably heated bowlders thrown out of the crater with or previous to the erupted flood, and borne down with it.

These observations indicate that the "mud flows" must be included with the primary volcanic phenomena of eruption as well as with the secondary.

VALLEY ERUPTIONS.

Perhaps no phenomena observed in the recent West Indian eruptions have led to more misinterpretation than the eruptions which were observed within the confines of valleys and canyons.

[1] *Mt. Pelée and the Tragedy of Martinique*, J. B. Lippincott Co.

[2] *Popular Science Monthly*, August, 1902, p. 359.

[3] *Century Magazine*, August, 1902.

Persisting after the great eruptions from the summit craters, they formed a source of intermittent anxiety to the inhabitants left near the borders of devastation, and one of considerable misinterpretation by the early explorers, who saw the voluminous outbursts only at a distance.

From afar these eruptions appeared as occasional outbursts of steam, whose snow-white bulging tops were sometimes mingled with tints of brown or shaded with deeper grayish color; "black mud" was reported to have issued from them; hence the name of "mud craters" was applied by some to the sites of these outbursts. Professor Angelo Heilprin, in his article, "Mount Pelée in its Might,"[1] speaks of "vents of the Falisse river acting as safety valves for Pelée." Professor Heilprin, in an account of his second visit to Martinique,[2] says:

> When my observations were made, I was not near enough to clearly ascertain its features, and relied for my determination largely on the observations of others. A closer examination of the gorge leads me to very strongly doubt the crateral origin of the outbursts—a doubt which has already been expressed by Lacroix and others.

Mr. Robert T. Hill, in his report on the volcanic disturbances in the West Indies[3] has prepared a map on which he locates three "mud craters," each over a mile from the crater of Pelée, and has located a "Soufrière crater" on the Rivière Blanche half way between the summit and the sea.

Of the hundreds of these eruptions from "lower craters" which I saw during the forty-eight days on these islands, one which occurred at the mouth of the Wallibou river, St. Vincent, on May 30, and another in the Sèche river on June 24, both witnessed at close range, may serve as the basis of a description of these phenomena.

While passing the Wallibou river in a dug-out canoe on the afternoon of May 30, a great cloud of vapor suddenly sprang from the stream, accompanied by a cannon-like roar. The column of steam rose to a height estimated at over 3,000 feet, and passed from a straight geyser-like jet into a bulging top ten

[1] *McClure's*, August, 1902.

[2] *Op. cit.*, p. 214.

[3] *National Geographical Magazine*, July, 1902.

times its base in width. Now and then black finger-like masses shot up into the curling vapor, were sustained for a minute or more, and then sank back out of view. At other times the jet appeared a solid column of black, during which the steam cloud would change from white to golden tints, and, as the violence increased, to grays. The black jets were composed

FIG. 4.— Delta at Basse Point. Showing encroachment of mud flows up the sea.

of erupted sand and rock fragments from the stream bed, and the changing color of the steam cloud indicated that some of the finer particles were carried even to its balloon-shaped top. Indeed, this erupted ash soon began to fall upon us until boat and crew alike were completely covered with a snow-like fall of gritty, gray dust. The eruption cloud itself quite simulated those from the crater of Pelée; the straight, black, rigid column at the base, the writhing, twisting puffs of brain-like formed globules with brownish hue above, and the lighter-colored, spreading pine-tree cloud on top which floated off with the trade wind in distinct globes, each indicating a different time of outburst.

It is scarcely a cause for wonder then, that these minor manifestations, with their spectacular appearance, were early regarded as originating from lateral craters connected with the main vents. From the location of these outbursts in stream beds it came to be reported that St. Pierre had probably been destroyed by a lateral crater in the bed of the Blanche river.[9]

ows up the sea. Half buried houses in foreground are close to the old shore line.

The particular eruption witnessed in the Wallibou took place about an hour after the beginning of a very heavy tropical rain which sent sand-filled water in sheets down over the sea cliffs and changing valleys. The river, which had maintained a mere showing of water, became a steaming torrent several feet in depth, instigating the explosion.

I was within the valley of the Sèche in the mud flow of June 24, when returning from an ascent to the crater of Pelée from the St. Pierre side, and saw in the bed of the avalanche-swept stream below, which we had just crossed in ankle-deep

[9] A. HEILPRIN, *McClure's*, August, 1902; R. T. HILL, *Century Magazine*, September, 1902; GEORGE KENNON, *Outlook*, Vol. LXXI.

waters, an eruption which threw its column of steam to a height of over half a mile. I found opportunity to visit the sites of both these explosions on the days following, and to examine them closely. From these and numerous other observations, especially in the Rozeau Dry river of St. Vincent, where the phenomena were best developed, it appears that the geyser-like eruptions may be explained as secondary phenomena.

FIG. 5.—Small, viscous mud stream —5 feet wide—flowing by pulsations in canyon north of Precheau.

Mechanics of "ash-geyser eruptions."—The beds of nearly all, if not all, of the rivers which head at the summit craters of La Soufrière and Mount Pelée contain deposits of volcanic ejecta generally known as "ash" in depths from a few inches to one hundred feet or more. This fragmental material ranges from the size of a block 22 by 50 by 24 feet in the Sèche river to impalpable dust. In some instances where the surface is more thickly strewn with bowlders, these rocks have been found to be hot enough to cause cracking of their surfaces, even fumerole-like deposits forming about them. In other places where the stream has deeply intrenched these deposits of volcanic ejecta, it has opened a passage between beds which are hot enough to burn the shoes, and clouds of mingled unconfined steam are given out whenever the hot dust slips into the stream water or the sea.

The mouths of the Blanche, the Sèche, and the Wallibou presented the best examples of these dissected hot-ash beds. When the bed of the stream was dry—its prevailing condition—little indication of this underlying high temperature within the deep stream deposits was apparent, save in the rare instances of hot bowlder surfaces and the mild steaming of the beds from small pits, through which hot vapor was sometimes rising, with the distinct blowing noise of escaping steam. These vents were

evidently outlets of underlying heated deposits, which, whenever reached by sufficient water, expressed themselves by the geyser-like eruptions.

Process of eruption.—Over the bed-rock bottoms of the peripheral streams a certain considerable amount of flood-plain deposit

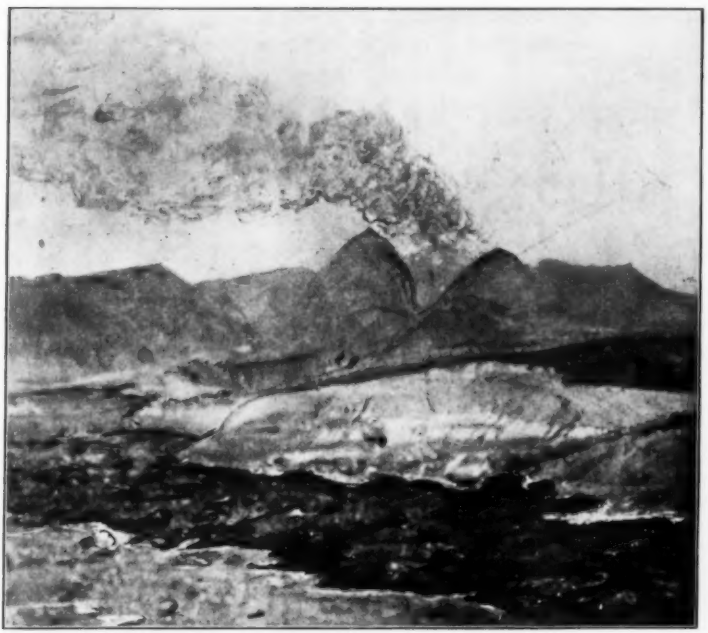


FIG. 6.—Mud flows on Blanche Lake divide.

had taken place before the eruptions. Upon this plain, and well up upon the including valley walls, were deposited hot volcanic ejecta of dust and bowlders. The high temperatures of the latter were maintained, aided by the blanket covering of overlying ash; and by their gravity they had tended to gather in the old river channel, forming loci of concentrated temperatures. Into these heated beds water percolated from above. The vapor generated by contact with the hot rocks increased until it sud-

denly found vent by eruption through the impounding beds; thus a chimney or vent was formed through which copious supplies of water were poured during the intervals of explosion, to be ejected again from the same pipe.

The instigation of eruption.—On reaching the hot, covered ash beds in sufficient quantities, the water must bring about geyser-like explosions until the underground heat is dissipated. There

FIG. 7.—An ash geyser eruption in the bed of the Wallibou river. Soufrière crater in the distance.

are a number of distinct processes by which this water manages to collect in sufficient quantities to instigate eruption. One is the flooding of the stream channel by a sudden tropical downpour, as observed on May 30; another is that of an eruption flood from the primary crater—as that from Mount Pelée on June 24. Still a third process, one of gradual accumulation, is that which obtains its water supply by the damming of the stream through landslides. I observed this in the Wallibou river at 8 o'clock on the morning of May 30. A portion of the undercut riparian ash banks had fallen, slipping across the channel, and by thus damming the stream caused a lake to form behind this barrier. When its water had reached and covered a certain place near

the right bank of the stream, an explosion suddenly took place, continuing with the usual attendant phenomena of "ash-geyser" eruptions. The explosion dug the bank rapidly away, adding the erupted detritus to the dam, which by rising increased the supply of water and the force of the explosions. Eventually the lake overflowed and a channel was cut back which, draining

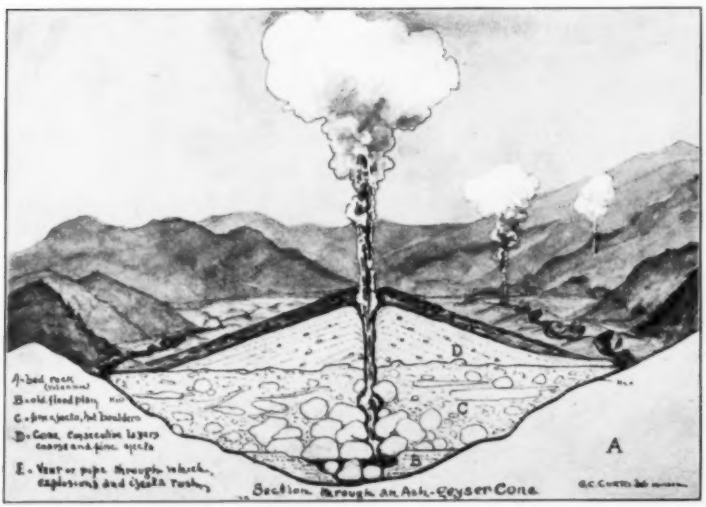


FIG. 8.

it by this outlet, brought a cessation of the eruption. The water may reach the hot-ash bed by filtration through the overlying deposit, or by pouring down the pipe or chimney when the orifice lies submerged.

Description of secondary cones.—The effects of these eruptions within the river courses simulate those of true volcanic craters. Steam rushes up through the overlying beds, carrying with it fragments from below and from the surrounding walls. It throws ejecta, composed of fine and coarse fragments (some were the size of a man's head), to a considerable height (that of a mile being observed), the finer material being doubtless scattered to distances of miles, but the coarse falling within the immediate vicinity of the vent. By gradual accumulation

this collection of sand and coarser fragments grows into a pile about the pipe, tending to assume the form of a perfect volcanic fragmental cone with crater falling into the descending pipe, and slopes averaging 25° to 30° (several cones 40 feet in

FIG. 9.—A secondary (or ash geyser) crater in the Rabaka river trenched by stream.

FIG. 10.—A secondary cone—ash geyser cone—partially demolished—Rabaka river. St. Vincent.

height and 160 feet in diameter were observed on both Martinique and St. Vincent).

The accompanying diagram (Fig. 8) represents the structure of the ash-geyser cone.

The ash-geyser, indeed, simulates a miniature volcano both

in topographic form and phenomena of eruption. Professor Russell asks:[1] "What is the crucial test by which a true crater may be distinguished from a pseudo-crater?" as he terms these secondary craters. Five characteristics were noted: first, location—the ash-geyser crater occurs persistently within the streams or the deltas; second, composition—the walls are con-

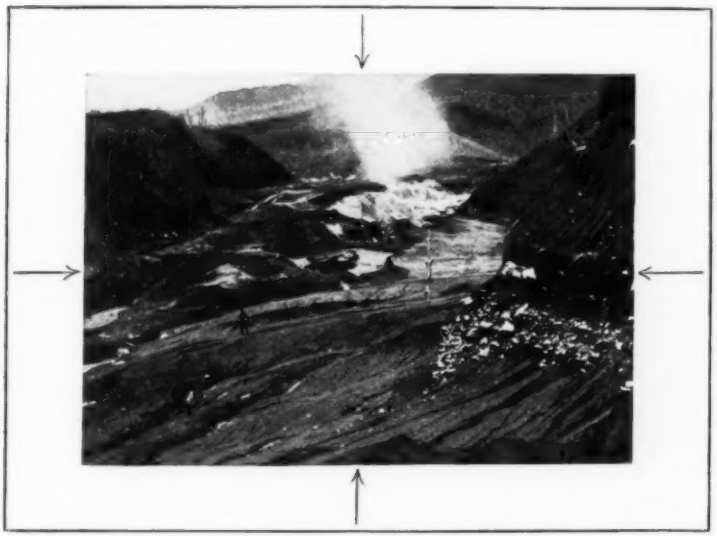


FIG. 11.—Ash cone topography and dissected ash cone lying in the present stream channel—Wallibou river. (Arrows point to cone).

structed entirely of fragmental material and not of old bedrock (the structural layers of the volcanic cone as observed on the rims of the primary craters); third, method of eruption—eruption occurs only in time of water accumulation; fourth, temperature—a relatively low temperature of ejecta; fifth, size—the ash-geyser cone is a small fraction of any true lateral crater observed. I am inclined to account for both the island discovered off the river Blanche on May 23,[2] and which had disappeared on return

[1] *National Geographical Magazine*, Vol XIII, No. 12, p. 416.

[2] R. T. HILL, *Century Magazine*, September, 1902.

to Martinique on June 14, and for the elongated hill of hot bowlders between the 600 and 700 foot level in the Sèche valley,[1] by secondary eruption.

Comparison of ash-geyser cones with other secondary volcanic cones.—These cones, occurring as they do within the valleys and upon

FIG. 12.—Secondary ash cone topography. Rabaka river. Vents slightly "steaming" with mere trickle of water in stream bed.

the "mud lavas," may be compared with those irregular heaps of volcanic scoriae which abound on the tops of some true lava streams, being piled up around each vent or "bocca" which the steam-jets escaping from the lava currents, form at their surfaces. The Vesuvian lavas of 1855 and of 1872 developed such cones on their surfaces.[2]

Ash-cone topography.—I was at first unable to account for the peculiar irregular topography in the channels of the streams soon after the great eruptions. It had the irregular rounded hillock appearance which resembled sand-dune forms. The sug-

[1] HOVEY, *Bull. American Museum*, Vol. XVI, p. 360.

[2] JUDD, *Volcanoes*, p. 101, drawing by Schmidt.

gestion was early offered that a rotary motion of tornadoes which emanated from the summit might account for the mounded topography. I am now persuaded that the rolling character of the stream deposits which doubtless originally had regular flood-plain cross-sections was largely due to this geyser action and to the presence of remnants of these secondary cones. These were left in every stage of demolition by shifting in the vents, by migration of the stream channels, by the degradation of the channel which carried the water surface out of reach of the main vent, or simply by the disappearance of the stream water.

GEO. CARROLL CURTIS.

GLACIATION IN THE BIGHORN MOUNTAINS.[1]

In Vol. IX of this JOURNAL a brief outline of the results of the work done on the glacial formations of the western mountains in 1901 was given. These studies were continued during the past summer. One of the parties, under the immediate charge of the junior author of this note, spent several weeks in the Bighorn mountains of Wyoming. He was assisted by Messrs. W. H. Emmons and F. W. DeWolf, while the senior writer was with the party for about a week at the beginning of the work.

In 1900 Mr. Matthes[2] gave a discriminating description of the cirques and other topographic features in the Bighorn mountains, due to glacial erosion. In the same year Professor W. C. Knight made mention of the former existence of glaciers in the same range.[3] When the party went into the field in 1902, Professor Knight furnished it with some general notes on the geology of the range, and in these notes there was a much fuller statement of the general facts concerning the distribution of glacial drift in these mountains than had hitherto been published by him. These data had been gathered by Professor Knight in the prosecution of his other work.

So far as known to the writers, no detailed study of the drift of these mountains had been attempted previous to their work in 1902, and up to that time the existence of more than one series of glacial formations had not been recognized. The studies of last summer revealed the existence of two series of glacial formations, separated from each other by a relatively long interval of time. A third series of deposits was found, much older than the older of the preceding, which may prove to be of glacial origin, though the evidence now in hand on this point is not regarded as conclusive.

[1] Published by permission of the director of the U. S. Geological Survey.

[2] *Twenty-first Annual Report U. S. Geol. Surv.*, Part II, pp. 173–90.

[3] *A Preliminary Report on the Artesian Basins of Wyoming.* Bull. 45, Wyoming Experiment Station, p. 174.

Existing glaciers.—Five small glaciers, all less than 1¼ miles in length, still exist in the mountains in the vicinity of Cloud peak at elevations exceeding 11,200 feet. In view of the fact that the annual snowfall is not great, while the altitude of the range is moderate, the highest point having an altitude of 13,165 feet, the persistence of these glaciers is probably due primarily to the exceptionally deep and narrow cirques in which they are situated, and by whose precipitous walls they are partially sheltered from the sun, and from desiccating winds.

Drift of the last glacial epoch.—The work of the latest series of glaciers in the Bighorns was similar to that which has been described from other ranges in the western mountains. They affected a tract about 45 miles long and 20 miles wide, extending from the head of the South Fork of Tongue river on the north to the head of the southernmost tributary of Clear creek on the south. The glaciers were, for the most part, of the simple valley type, though in many cases the glaciers of several tributary valleys united into one, in the main valley below. Nowhere was there a well-developed ice-cap, though the expanse of ice in some of the valleys was considerable. In length the glaciers varied from 1 to 14 miles, and the largest of them crossed the plateau above which the sharper part of the range rises, but in no case did they reach the plains beyond.

The altitude necessary for the development of glaciers was rather more than 10,000 feet in most of the valleys, but one glacier (South Fork of Tongue river) was developed at an elevation of little more than 9,000 feet. In this case there was a favorable catchment basin on a north slope, protected against warm, drying winds.

About forty-five well-developed cirques are shown on the Cloud peak quadrangle. All of them were occupied by glaciers of the last glacial epoch, and all but two of the late Pleistocene glaciers had their sources in cirques, and were concerned in their formation. The exceptions were the feeble tongues of ice at Dome lake, and at the head of the South Fork of Tongue river.

Not counting the small feeders of larger glaciers, the deposits

of twelve distinct glaciers or systems of glaciers were studied. They occur in the following valleys:

	Length.
1. Four tributaries of the South Fork of Clear creek, the several glaciers uniting into one below	about 6 miles
2. Little cliff-glacier, south of the South Fork of Clear creek,	" 1 mile
3. Middle Fork of Clear creek	" 1 "
4. South branch of the North Fork of Clear creek	" 4 miles
5. North Fork of Clear creek	" 10 "
6. South Fork of South Piney creek	" 8 "
7. North Fork of South Piney creek	" 12 "
8. East Fork of Big Goose creek	" 9 "
9. West Fork of Big Goose creek	" 8 "
10. South Fork of Tongue river	" 6 "
11. Willett creek	" 3 "
12. Shell creek	" 14 "

In addition to the above, glacial formations are known in the following valleys, though they were not studied in detail during the past summer:

13. Trapper creek.
14. North Fork of Medicine Lodge creek.
15. South Fork of Medicine Lodge creek.
16. North Fork of Paintrock creek.
17. Middle Fork of Paintrock creek.
18. Buckskin Ed creek.
19. Tensleep creek.

The glaciers of the last glacial epoch made deposits consistent with their various sizes and activities. In general, the lateral and terminal moraines are more conspicuous than the ground moraines, while the amount of drift is slight near the sources of the glaciers, and great below. The lateral moraines are long, sharp ridges, paralleling the sides of the valleys, and have rather even crest-lines, 500–700 feet above the streams. Their proximal ends usually lie against the rocky sides of the glacial canyons at an elevation of about 10,000 feet, while their distal ends merge into the stout terminal moraines. The outer fronts of the terminal moraines frequently rise somewhat abruptly 400 to 500 feet above the valley below, and their surfaces often possess in a notable degree the hummocky topography characteristic of these formations. Valley trains are present below the terminal moraines, but they are not usually very conspicuous.

One of the most striking features of the youngest series of glacial deposits is the extremely fresh appearance of the drift, and the trivial extent of the inroads which weathering and erosion have made on it and on the rock of the canyon walls and *roches moutonnées* within the area where it occurs. The till often shows scarcely a trace of surface oxidation. The numerous lakes in the valleys occupied by the glaciers of the last ice epoch, many of them confined by drift dams in valleys which have steep gradients and copious drainage, are clear indications of the

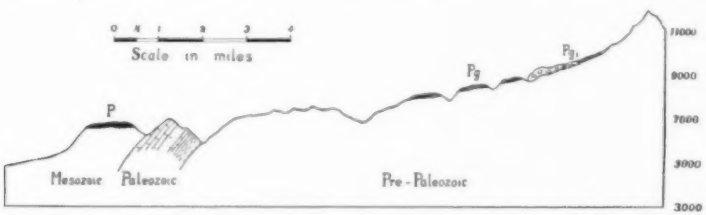


FIG. 1.—Section from near Fort McKinney to the head of the South Fork of Clear creek, showing the distribution of the Pleistocene formations: *P*, Bald mountain beds; *Pg*, drift of the next to the last glacial epoch; Pg_1, drift of the last glacial epoch.

recency of glaciation. The amount of postglacial stream erosion has been slight in most cases. It is at a maximum where the streams cut through the terminal moraines, where V-shaped gorges, 50 to 100 feet deep, have been cut in the till; but inasmuch as a single flood in Piney creek in the spring of 1902 cut a channel 10 to 20 feet deep, these figures must be regarded as small. In addition to the signs of freshness in the drift itself, striæ still remain on exposed surfaces of granite.

Glacial drift antedating the last.—In most of the valleys examined there are bodies of glacial drift outside of the fresh moraines referred to above, and of notably greater age. Their glacial origin is established both by the disposition of the drift in the form of well-defined lateral moraines, and by the finding of striated stones in the fresh exposures.

Their greater age is shown by the topography of the drift, by the physical condition of the material, by its topographic position, and by its patchy distribution (*Pg*, Fig. 1). The

details of the topography of this older drift, and in many cases even its larger features, are no longer glacial, but erosional. Any lakes which once existed in its surface seem to have disappeared long before the advent of the glaciers of the last epoch. This is true at any rate of that part of the drift which lies outside the newer drift, the only part now exposed. The surfaces of the *roches moutonnées* within the area of the older drift have been weathered into roughness, many of them being angular crags, while deep valleys have been cut into the drift, and 100 to 500 feet into the underlying crystalline rock. In most cases no traces of terminal moraines were found at the limit of this series of older drift deposits. From their position, such moraines were the first part of the drift to be removed. Portions of old lateral moraines are, however, preserved in some of the valleys, such as that of North Fork of Clear creek, East Fork of Big Goose creek, and at Penrose park. They have suffered considerably from stream erosion, but the even crest-line and ridge-like character are sometimes still distinct.

In general, this body of drift has been rendered notably discontinuous by erosion. The remnants are often so meager that accurate mapping of the outlines of the glaciers which made it is not practicable, though their approximate limits can usually be ascertained. In many places the remnants are restricted to hilltops.

A formation of still older (glacial ?) drift.—From the foregoing, it is clear that the Bighorn mountains were subjected to two distinct glacial régimes in the Pleistocene period. That there was a still earlier epoch of glaciation is suggested, though not proved, by the data now in hand concerning a series of deposits which antedate the older of the drift formations referred to above. Gravel, some of it containing bowlders, is widespread about the mountains. It covers the dissected plains and caps the hills which rise above them. Most of this gravel is regarded as the work of waters flowing out from the mountains and spreading on the plains. These gravels are of various ages, as their varying topographic positions show, and the oldest antedate, by some considerable period, the glacier deposits of the last

two glacial epochs. While most of the gravels seen gave no evidence of being glacial, there is on certain of the hills west of Buffalo, especially on the summit of the mountain locally known as Bald mountain[1] about six miles west southwest of Buffalo, a deposit of unconsolidated material which has something of a

FIG. 2.— Section of the drift on the summit of Bald mountain.

glacial aspect (*P*, Fig. 1). It is made up of bowlders and stones set in a matrix of finer material (Fig. 2).

All the bowlders, so far as seen, are of igneous or metamorphic rock derived from the pre-Cambrian core of the range, the nearest part of which is more than a mile west of the locality in question. Most of them appear to have come from the higher part of the range, some 8 or 10 miles away. This material must have come across the intervening Paleozoic beds,

[1] There is another Bald mountain about 40 miles northwest of Cloud peak (see Bald Mountain quadrangle).

though no Paleozoic material was found in the deposit. This is the more remarkable since some of the gravels at lower levels in the vicinity contain a large proportion of Paleozoic material. The thickness of this body of drift was not determined, but it probably exceeds 100 feet. The plateau surface between Bald mountain and the known glacial drift has not been studied in sufficient detail to affirm that drift is absent from it, but, if present, it is certainly scattering and meager in the region visited.

In connection with the problem of the transportation of this detritus, streams and glaciers are the only agents whose claims need to be considered. Positive evidence in favor of a fluvial origin is absent, so far as known data are concerned, and the existence of numerous bowlders 15 to 25 feet in diameter militates against it, especially as the gradient between the source of the bowlders and their present position is not such as to make their reference to streams seem plausible. The summit of Bald mountain has an elevation of about 7,000 feet, and the (dissected) plateau level of the crystalline schists to the west has an elevation of about 8,500 feet some 10 miles. Bald mountain is, indeed, an isolated remnant of this plateau, the surface of which declines eastward from the base of the high part of the range which rises above it. A gradient of 150 feet or less per mile would be altogether inadequate for the transportation of such bowlders as occur on Bald mountain, by any stream which could have had its origin in this range. If river ice be assumed, the difficulty is somewhat relieved, but by no means eliminated. It is to be recognized, however, that the surface gradient may have changed since the deposit was made.

The general constitution and structure of the material are consistent with its glacial origin, though, except for the great size of some of the bowlders, perhaps not inconsistent with a torrential origin. If the deposit be glacial, the large bowlders present no difficulty, though the absence of Paleozoic material is as difficult of explanation on this hypothesis as on the other. No unequivocal striæ were found on the stones of the deposit, though somewhat careful search was made for them. Numerous

stones and bowlders were found the surfaces of which had the appearance of having been glaciated, but none which could be regarded as decisive. The failure of distinct striæ is perhaps not to be wondered at, since most of the material is so deeply weathered that but few of the bowlders retain much of the original surface. Many of the bowlders, indeed, are decayed to their centers, and many more have thick coatings of oxidized material. Furthermore, in the younger glacial drift of the present valleys, these same sorts of rock are striated but rarely.

The drift-like material on Bald mountain is separated from the Paleozoic terranes to the west by a valley 500 feet or more in depth. Farther west, a valley 1,000 feet or more in depth separates the Paleozoic terranes from the crystalline rock, whence the débris in question was derived. Whatever its origin, the drift appears to have reached its present position before these valleys were excavated. Its topographic position therefore, as well as its physical condition, points to its great age, an age which must antedate the older body of certain glacial drift (*Pg*, Fig. 1) by an interval of time greater than that which separates the two formations of known glacial drift.

Deposits which have some similarity to that on Bald mountain have some development elsewhere, but nowhere else was the suggestion of glacial drift so strong as on Bald mountain.

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NOTES ON THE MARINE SEDIMENTS OF EASTERN OREGON.

THE marine sediments of eastern Oregon comprise beds ranging from the Carboniferous to the Upper Cretaceous. The Carboniferous and Triassic have been described by Waldemar Lindgren,[1] the Jurassic by Alpheus Hyatt,[2] and the Cretaceous by John C. Merriam,[3] C. A. White,[4] W. M. Gabb,[5] J. S. Diller and T. W. Stanton,[6] and Professor Blake.[7] The present paper is written to demonstrate the Carboniferous age of the limestone of Baker county, and to describe new localities of the Paleozoic and the Mesozoic in eastern Oregon.

The Carboniferous.— Lindgren[8] has described and mapped a great series of metamorphic argillites and limestones in Baker county, which he refers with doubt to the Carboniferous. Fossils are scarce in these rocks, the only ones reported by Lindgren being some round crinoid stems.

In the early eighties some fossiliferous limestone was sent to Professor Condon from Powder river, below Baker City. Professor Condon recognized the fossils as *Producti*, and hence sufficient to prove the Carboniferous age of the Baker county limestone that Lindgren maps as Carboniferous. Recently, through the help of Mr. H. G. Moulton, Mr. N. C. Haskell, Mr. Thomas Burke, and Mr. L. W. Nelson, of Baker City, the position of the

[1] "Gold Belt of the Blue Mountains," *Twenty-second Annual Rept. U. S. Geol. Surv.*, Part II, pp. 577–82, 1902; *Science*, Vol. XIII, pp. 270, 271, 1901.

[2] "Trias and Jura in the Western States," *Bull. Geol. Soc. Am.*, Vol. V, pp. 418–20, 1894.

[3] "Contribution to the Geology of the John Day," *Bull. Dep't Geol., Univ. of Calif.*, Vol. II, No. 9, pp. 280–85.

[4] *Bull. 33, U. S. Geol. Surv.*, p. 19; *Bull. 15*, pp. 31, 8; *Bull. U. S. G. S. Terr.*, Vol. II, p. 359.

[5] *Paleon. Calif.*, Vol. II, pp. 138, 181.

[6] *Bull. Geol. Soc. Am.*, Vol. IV, pp. 214, 452, 453.

[7] *Am. Jour. Science*, 1867, p. 118.

[8] *Twenty-second Annual Rept. U. S. Geol. Surv.*, Part II, p. 578.

limestone has been ascertained and more fossils collected from it. Mr. Nelson writes that he found the fossils *in situ* in limestone east of Big creek, about three miles south of Medical Springs. He says that the limestone extends in a broken line through Tp. 7 S., R's. 41, 42, and that it contains fossils in many places. Lindgren's map shows only Triassic in this vicinity. The fossils were referred to Dr. George H. Girty, to whose kindness the writer is indebted for the following report:

The unfortunate preservation of the material from Oregon is such as to render a nice discrimination of species impossible. Among the *Producti* there appear to be at least three species, one of these a large, comparatively flat, and spreading shell, which cannot be identified. Another group consists of small shells, which can be almost exactly duplicated in *Marginifera splendens* N & P of the Mississippi valley, a species frequently cited as *Productus longispinus*. I have not, however, been able to make out the internal characters distinguishing the genus *Marginifera*. The third group comprises forms more or less closely related to *Productus multistriatus* Meek. All of these specimens are smaller than typical *P. multistriatus*, and some are more coarsely striated. These shells vary so much in these two characters, size, and striation, that I suspect that more than one species is represented. The material, however, will not permit this fact to be satisfactorily determined. Besides the forms mentioned are a *Spirifer* or *Spiriferina* (probably the latter), a *Seminula* not unlike some forms of *S. subtilita* from the Mississippi valley.

The only other place in eastern Oregon in which Paleozoic fossils have been found is on upper Crooked river. The fossils occur in partly crystalline limestone on upper Beaver creek, near the crossing of the Prineville-Izee wagon road. They were discovered by Mr. John Platts and the writer while on a bicycle trip in 1899.

Dr. Girty reports on them as follows:

The following species have been identified:
Zaphrentis sp.
Brachiopod?
Aviculopecten sp.
Pseudomonotis sp.
The shell referred to as Brachiopod is indeterminable.

The third-mentioned form is probably an *Aviculopecten*, but it belongs to no species with which I am familiar, and certainly not to the common Carboniferous ones.

A species of Zaphrentis seems to be quite common and, as this type of coral is restricted to the Paleozoic, its presence seems to indicate, though broadly, something definite with regard to the age of the beds.

The fourth form, however, is somewhat contradictory. Several paleontologists to whom I have shown it know nothing similar to it in the Paleozoic. I am forced to conclude either that it is something entirely new or that its preservation has obscured its real character. It seems to resemble *Pseudomonotis* more than any other genus I know, but it is quite unlike, in its peculiar surface markings, any members of the genus yet found in this country. *Pseudomonotis*, it should be remarked, is especially distinctive of the Permian period.

On the whole, I am forced to conclude that the fauna indicates Carboniferous, though it may, in fact, be Devonian. Evidence of a more conclusive character is desirable to really establish the age of these beds.[1]

The *Aviculopecten* mentioned by Dr. Girty was not found in the limestone with the other fossils, but in siliceous shales which dipped away from the limestone for at least ten miles eastward to Izee post-office, where the fossil was found. The shales are well exposed along the north side of the south fork of the John Day for several miles below Izee. How far they continue east of Izee I do not know, since we turned north at Izee and passed over basalt most of the distance to Canyon City. All of the rock that was not basalt was on the Canyon City end of the road and either serpentine or coarse-grained igneous rock. The shales on the south fork did not seem as much metamorphosed as the Pitt shales of northern California and would likely yield plenty of fossils. From the fact that they overlie the Paleozoic limestone and dip toward undoubted Jurassic strata twenty-five miles southeast, the shales are possibly Triassic.

The Triassic.—The Triassic was first reported from eastern Oregon by Waldemar Lindgren.[2] From Lindgren's beds near Wallowa Lake, in T. 3 S., R. 44 E., Secs. 9, 10, 14, 15, 35, 36, a great many *Halobiae* have been sent to Professor Condon by Mr. Charles Cambell, Mr. Oglesby, and others. The collections

[1] No "well-defined Carboniferous," nor indeed any Paleozoic but this, has been reported from Crooked river. Lindgren was mistaken in thinking Professor Condon had found such rocks there. (*Twenty-second Ann. Rept. U. S. G. S.*, Part II, p. 579.)

[2] *Twenty-second Ann. Rept. U.S. Geol. Surv.*, Part II, pp. 579–81, 1902; also *Science*, Vol. XIII, pp. 270, 271, 1901.

have not yet been thoroughly studied, but contain probably *Halobia rugosa*, Guembel, aud two undetermined species.

The Jurassic.— Hyatt[1] described fossils from eastern Oregon which he thought came from Beaver creek, a tributary to Crooked river. The specimens are now in the Condon Museum, University of Oregon, and include, according to Hyatt:

Pecten acutiplicatus Meek.
Pholadomya nevadana Gabb.
Pholadomya multilineata Gabb.
Pleuromya concentrica Hyatt.
Cardinia gibbosum (?) Meek.
Rhynchonella sp.

These fossils did not come from Beaver creek, but from Silver river, over thirty miles east of Beaver creek, where they were found by William Day, of Dayville, Ore.

Professor Condon has obtained another collection made at Red Butte, Tp. 19 S., R. 30, about twenty miles north of Burns. This collection was sent to him by Mr. A. H. Huntington, of Baker City. It includes:

Pecten acutiplicatus Meek.
Pholadomya nevadana Gabb.
P. multilineata? Gabb.
Entolium meeki Hyatt.

The third-mentioned form bears some resemblance to *P. inaequiplicata* Stanton. There are also some undetermined bivalves and ammonites in the collection. The fauna is that of the Hardgrave sandstone of Taylorville.[2]

Though the fossils studied by Hyatt did not come from Crooked river, it is probable that the Jurassic does occur there. In 1862 Professor Condon picked up a few shells on lower Beaver creek that seem to belong to that period. Mr. Stanton says of them:

> The fossils from Beaver creek include a *Gryphea*, two casts of an *Ostrea*, a *Pecten*, and probably two species of *Rhynchonella* related to *R. gnathophora* Meek. I am unable to give specific identification of any of the forms, and they do not give any certain indication of the horizon from which they came.

[1] *Bull. Geol. Soc. Am.*, Vol. V, pp. 401, 418–20.

[2] *Bull. Geol. Soc. Am.*, Vol. V, p. 401.

They are certainly Mesozoic, however, and I think Jurassic rather than Cretaceous.

The Knoxville Cretaceous.— On petrographic and stratigraphic grounds Merriam[1] has recognized the Knoxville and the Chico near Mitchell, Wheeler county. His conclusions are supported by the evidence of the following fossils collected by Professor Condon in 1863 from various places between Mitchell and the John Day:

Oleostophanus sp.
Nautilus texanus (?) Shumard.
Acteonella oviformis Gabb.
Trigonia leana Gabb.

There are also two ammonites, one of them probably *Scaphites*, that the writer cannot classify. The first-mentioned form is a fragment that seems to be closely related to *O. Mutabilis* Stanton, a characteristic Knoxville species.[2] The other three species probably came from the strata that Merriam regarded as Chico. An interesting problem in Cretaceous geography will be solved when it can be proven that the Knoxville is present or absent in eastern Oregon, and it is to be hoped that someone will secure such proof. No *Aucellae* have yet been found there.

The Chico.— The first record of the Chico in eastern Oregon was made by Whitney,[3] who published some fossils collected by Gabb on Crooked river. In the same year Blake[4] described a *Turrilites* and other fossils that Professor Condon had collected at the same place. Since then several writers[5] have referred to the Chico in eastern Oregon, from knowledge that they gained from Professor Condon's Spanish Gulch and Crooked river fossils. Recently Merriam[6] has made large collections at the Spanish Gulch locality.

On upper Beaver creek John Platts and the writer made a

[1] *Bull. Dept. Geol., Univ. of Calif.*, Vol. II, p. 285, 1901.

[2] See STANTON, *Bull. U. S. Geol. Surv.*, No. 133, pp. 17, 18, 27, 77.

[3] *Proc. Cal. Acad. Nat. Sci.*, Vol. III, p. 309, January, 1867.

[4] *Am. Jour. Sci.*, July, 1867, p. 118.

[5] See footnotes on first page of this paper.

[6] *Bull. Dep't Geol., Univ. of Calif.*, Vol. II, pp. 418–20.

hasty collection of fossils, from dark-colored sandstones that were not unlikely the source of the earlier collections. The sandstone contains several beds of conglomerate, composed largely of pebbles of argillite and black chert. It dips gently northwest and rests unconformably upon the Paleozoic limestone mentioned above. Some of the fossils were obtained within a few feet of the limestone, in a conglomerate that contained an occasional pebble of the limestone. We did not have time to learn much about the distribution of the sandstone, but since the road up Crooked river had been entirely through Tertiary sediments and lavas, and the road beyond was through older rocks, it is not likely that the Chico covers much ground. Our collection was referred to Mr. Stanton, to whom we are indebted for the following list of species:

Hemiaster californicus Clark.
Exogyra parasitica Gabb.
Ostrea sp.
Gervillia sp.
Inoceramus sp.
Trigonia evansana Meek.
Homomya concentrica Gabb.
Dentalium stramineum Gabb.
Gyrodes expansa Gabb.
Lunatia sp.
Amauropsis sp.
Anthonya cultriformis Gabb.
Meretrix varians Gabb.
Dosinia elevata Gabb.
Tellina ? sp.
Anatina quadrata Gabb.
Pholadomya sp.
Acteonina californica Gabb.
Tritonium sp.
Fusus sp.
Ituvis sp.
Desmoceras dawsoni Whiteaves.

Mr. Stanton says:

> The present collection is interesting from the fact that it contains a considerable number of new species. Nearly all the forms that are only generically determined appear to be undescribed. A larger collection of fossils from this locality, with a description of the beds in which they occur, is very desirable.

It is evident that the same need exists for all the Paleozoic and Mesozoic rocks of eastern Oregon.

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REED CITY METEORITE.[1]

For the early history of this meteorite I am indebted to Professor Walter B. Barrows, of the Michigan State Agricultural College, and to a clipping from an article written by Professor Barrows in the *M. A. C. Record*, published by the same institution.

This meteorite, according to Professor Barrows's statement, was found by Mr. Ernest Ruppert, a small farmer and junk dealer, on his farm in Osceola county, near Reed City, Mich., while plowing in September, 1895. Later the meteorite was displayed in a hotel window in Reed City, where Professor Barrows saw it in December, 1898, and was told there had been a dispute as to the origin of the specimen, some claiming that it was a meteor from the skies, others that it was a lump of ordinary iron. Professor Barrows saw at a glance from its general character that it was a genuine meteorite and at that time made an unsuccessful effort to obtain it for the college museum. Other attempts were equally unsuccessful, until recently when the iron was purchased by the college.

In January of this year Professor Henry A. Ward, of Chicago, visited Professor Barrows to see if he could not make arrangements to obtain a portion of the mass for the Ward-Coonley Collection of Meteorites now on deposit in the American Museum of Natural History in New York. In consequence of this visit, the mass was sent to Rochester, N. Y., for slicing.

The meteorite before cutting was a semicircular or ham-shaped mass $10 \times 21 \times 26\frac{1}{2}$ cm in its greatest diameters. One side (Fig. 1) has a comparatively smooth convex surface showing no distinct pittings; the opposite side is much more irregular in form, slightly concave, with three prominent and numerous small characteristic pittings. On the upper edge of this face is a hackly fracture oblong in shape $4\frac{1}{2} \times 10$ cm in diameter, where a piece of less than a pound, according to Professor Barrows,

[1] Read before Rochester Academy of Science, March 9, 1903.

was broken off by the finder in an effort to discover what made the "stone" so heavy. The surface of this fracture, like that of the entire mass, is much oxidized, so that the nickeliferous iron is not visible. On one edge there is a large irregular pitting some 10^{cm} long and 5^{cm} deep. The whole mass is of a reddish-

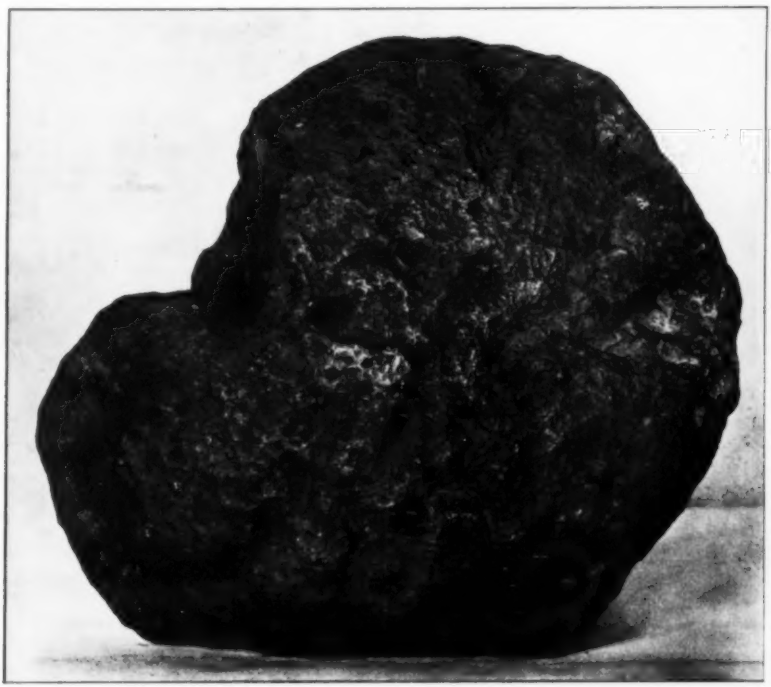

FIG. 1.—Showing convex surface. Three-fifths actual size.

brown hue, intermingled with large irregular patches of an ochre yellow color. On no part of the iron was the true crust observed. Its weight was 43 pounds 11 ounces, or 19.8 kilograms.

Following the directions of Professor Ward, a few cuts were made parallel to the upper left-hand edge (Fig. 1), showing the deep pitting mentioned above, and commencing just within the

edge of this pitting. On polishing and etching these cut surfaces, we found that the iron was octahedral in structure, with well-marked Widmanstätten figures. A feature of this iron is the fact that it etches so readily that the Widmanstätten figures were slightly outlined on an ordinary polished surface, without the use of acid or any other solvent.

The etched surfaces have numerous fissures from ½ to 1½^{mm} in width and from 5 to 65^{mm} in length, partly filled with

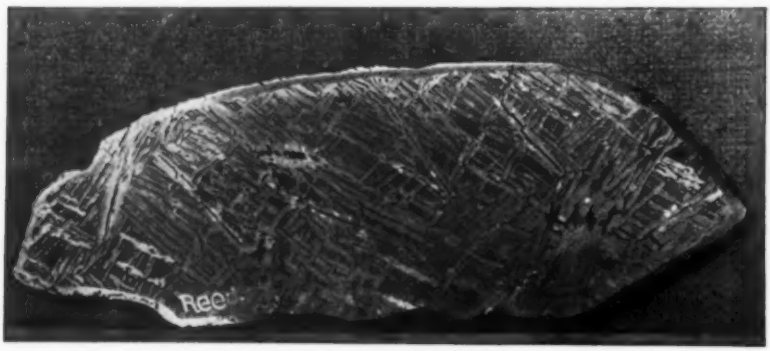

FIG. 2.—Section showing Widmanstätten figures. Three-fifths actual size.

troilite, but mainly with schreibersite. These fissures occur at various angles toward each other, thus breaking to some extent the regularity of the Widmanstätten figures, and are invariably entirely surrounded by kamacite bands. The kamacite bands average from 1½ to 2^{mm} in width, with the broadest bands generally surrounding the schreibersite-filled fissures as seen in Fig. 2. The plessite patches which are quite prominent on the etched surfaces show clearly the alternating layers of kamacite and taenite (so-called Laphamite lines) a feature that was first distinguished in another Michigan iron, that of Grand Rapids. On no section were rounded troilite nodules, so characteristic of iron meteorites, found.

The character of the etched surface of this meteorite in many respects resembles that of Cuernavaca, but the kamacite blades

are much broader and longer than in Cuernavaca, thus making the figures much more prominent.

An analysis of this meteorite made for Professor Ward by Professor J. F. Whitfield, of Philadelphia, gave the following results:

Fe. 89.386.
Ni. 8.180.
Specific gravity is 7.6.

From the close proximity of the farm on which this meteorite was found to Reed City we will designate it as the "Reed City Meteorite."

The main mass of this iron was returned to the Michigan Agricultural College, while the smaller end and one slice weighing 2.9 kilograms were added to the Ward-Coonley Collection of Meteorites.

Michigan has to the present time furnished but three meteorites to the scientific world as far as described:

Grand Rapids - - - - - -	found 1883
Reed City - - - - - -	found 1895
Allegan - - - - - -	fell July 10, 1890

The first two are siderites, the last an aerolite.

H. L. PRESTON.

ROCHESTER, N. Y.

Reviews.

Report of the Vermont State Geologist, 1901–1902. 190 pages; 62 plates; 2 maps.

This volume seems to mark, in a way, a fresh start in geological work in Vermont, made possible by more adequate provision for the work of the state geologist. The first thirty pages are devoted to a résumé of past geological work in the state, including (1) a sketch of the life of Zadock Thomson, state geologist 1853–56, together with a list of his publications; (2) a list of reports on the geology of Vermont, 1845–1900, with a summary of the scope of each report; (3) a list of other publications bearing on Vermont geology; and (4) a biography of Mr. Augustus Wing (1808–76), an independent investigator who made important contributions to the knowledge of Vermont geology.

Then follows a summary of the metallic products, useful minerals, and building-stones of the state. Mr. George I. Finlay contributes the results of a study of the Barre Granite area, one of the most important granite areas in the country, the workshops at the Barre quarries being the largest of the kind in the world. A detailed petrographical description is given of the granites and their associated rocks.

"The Terranes of Orange County" are discussed by Dr. C. H. Richardson. The slates of Montpelier and Northfield, and those extending north and south from Bradford, which have been regarded as Cambrian, are placed by him in the same horizon with the "Calciferous Mica Schist" of Hitchcock, on stratigraphic grounds. The latter is separated by Richardson into a calcareous member, the Washington limestone, and a non-calcareous member, the Bradford schist. These have been regarded by most geologists as Silurian (Upper Silurian), but are placed by the author, together with the slates, in the Lower Trenton, on the ground of the lithological similarity of the slates with the graptolitic slates of Trenton age at Willard's Mill and Castle Brook, Quebec. The slates are shown to rest unconformably on the Huronian, and so the Cambrian, according to this classification, is absent. A more detailed statement and discussion of the evidence for this important change of correlation would be of interest. It may be noted that in accounting for the break in the outcrop of the slates near Bradford by erosion

(necessarily previous to the deposition of the Bradford schists), the writer presumes an erosion interval between the very beds (Washington limestone and the slate) which he classes together (see p. 78 and Plate XIV).

"The Geology of Grand Isle" is the subject of a chapter by Dr. Perkins. This is the largest of the islands of Lake Champlain. The term "Champlainian" is used instead of "Ordovician," and "Beekmantown" instead of "Calciferous," upon grounds of priority. The much-folded and tilted Utica shales, resting on only slightly disturbed Trenton and Chazy beds, afford an excellent example of the different effects which the same orogenic movements may have on strata of different lithologic character and in different stratigraphic positions.

Peculiar concretion-like organic remains in the Chazy are believed to be sponges, and are placed by H. M. Seely in a new genus, Stephochetus. Four new species of this genus are described and figured. A petrographic description of the dikes of Grand Isle is given by H. W. Shirmer, of Columbia University.

The illustrations are numerous and especially good.

E. S. B.

Mineral Resources of the United States. Calendar Year 1901. By DAVID T. DAY. United States Geological Survey.

THE total value of our mineral production was $1,086,529,521 — a gain of 2.15 per cent. over that of 1900. For the second time it was more than a billion dollars. The twenty-two products whose value exceeded a million dollars each are, in order of their value, as follows: Coal, pig iron, copper, gold, silver (coining value), petroleum, stone (building), natural gas, lead, cement, brick clay, zinc, mineral waters, salt, phosphate rock, limestone (for iron flux), zinc white, clay (other than brick), aluminum, gypsum, quicksilver, and pyrite.

Coal.—The coal product of the United States for the year 1901 was the greatest in the history of the industry, its value being $348,910,464 — an increase of 14 per cent. The tonnage exceeded that of Great Britain and colonies, and was 75 per cent. greater than the output of Germany. The industry gave employment to 485,544 men. There were twenty-eight states and territories producing coal, and twenty-two of them show increased output, the greatest per cent. increase being that of North Dakota. Pennsylvania produced 51 per cent. of all the coal mined. Illinois ranked second with 9.6 per cent. West Virginia, Ohio, Alabama, Indiana, Kentucky, Colorado, and Iowa follow in the order named.

The anthracite product was $112,504,020 — an increase of 31 per cent. over that of the previous year. The average price at the mine was $2.05 per long ton, Pennsylvania producing all of this, though true anthracite has been produced for a number of years in Colorado and New Mexico.

The bituminous product was valued at $236,406,449. Of this the Appalachian field produced 67 per cent.; the central field (Illinois, Indiana, Kentucky), 16 per cent.; the western field (Iowa, Missouri, Kansas), 9 per cent.; the Rocky Mountain field, 6 per cent.; the coast field, 1 per cent.; and the Michigan field, ½ per cent. The average price at the mine was $1.05. The report includes statistics of labor, of accidents, and of the use of mining machinery, given by states.

The product of coke, included under coal, was $44,445,923. It is shown that by the beehive ovens now generally in use $18,000,000 worth of by-products, exclusive of gas, was wasted. Nor is this due to a lack of demand for these products, for we are paying, principally to Germany, $10,000,000 a year for these materials.

Petroleum.—The production of crude petroleum for the year was valued at $66,417,335 — the greatest in the history of the industry. There was a very remarkable increase in the production of Texas and California, a decrease in the Appalachian field, and a small gain in the Lima-Indiana region. The exports of petroleum products were the largest ever recorded, although there was a slight decrease in their value. The development of new pools in Texas, California, and at Boulder, Col., was attended by the organization of 1,478 companies representing a capitalization of $663,283,000. Of these only 556 produced petroleum. Prices varied from $0.28 per barrel in Texas to $7 for the natural lubricating oil of Wyoming. The average price was $0.96. From the results of analyses of the Beaumont petroleum the opinion is that, though it is eminently fitted for a fuel, the present known methods will fail to secure illuminating and lubricating derivatives in sufficient quantity to justify its refinement. The wide distribution and great production of the Texas fields "seem to assure the final result that Texas will in the course of time be at the head of the list of oil-producing states in this country."

New discoveries of oil in California are of far-reaching importance. There practically all of the coal must be imported, coming largely from British Columbia and Australia. This has prevented San Francisco from becoming a great manufacturing center, but this situation need no longer exist, for sufficient oil at low prices is piped directly to the

city from the Kern county district. Like the Texas oil, the California product is low in illuminating and high in heating power, three and one-half barrels being equivalent to a ton of coal. The report includes extensive reviews of the oil production of the world.

Natural gas.—The value of the product was $27,067,500—an increase of 14 per cent. over the previous year. The pressure, however, has continued to decline, necessitating the expense of compression in order to market an increased production from declining fields. A total of 709,921 domestic fires and 5,742 factories and mills were supplied. The increase per cent. in production was greatest in Kansas.

Iron ore.—The production of 28,887,479 long tons was 5 per cent. greater than the production of any previous year and greater than the output of any other country, exceeding that of Germany, our nearest competitor, by more than 50 per cent. Of the twenty-five states mining iron, Minnesota ranked first, Michigan second, and Alabama third. The ores were hematite 93 per cent., magnetite 6 per cent., and carbonate less than 1 per cent. The Mesabi range in Minnesota, owing to the large deposits and the ease of working them, produced 32 per cent. of the total for the United States. About 200 cargo analyses of Lake Superior iron ore are given. The production of pig iron was worth $242,174,000 and exceeded the combined British and German production for the same year.

Gold.—The production for the year was $78,666,700—a decrease of 0.6 per cent. California increased her production over a million dollars and Nevada almost as much, her increase coming largely from the new camp of Tonapah in Nye county. Alaska and Colorado showed a decrease of about a million dollars each. The principal producing states and territories, in order of production, were as follows: Colorado, California, Alaska, South Dakota, Montana, and Arizona. About 85 per cent. of the production came from quartz and the remainder from placer mines.

Silver.—The commercial value of the yield was $33,128,400—about 4 per cent. less than that of the previous year. The greatest gain was in Utah, most of which came from the Park City district. Colorado and Montana showed a material decrease. About 29 per cent. came from quartz mining and the remainder from lead and copper ores.

Copper.—The year's production was valued at $87,300,515—a decrease of 11 per cent. This decrease was due chiefly to the lower

prices prevailing, the quantity mined falling off less than 1 per cent. The product of the United States was considerably more than that of all other countries combined. Of this Montana produced 38 per cent., the Lake Superior region 26 per cent., and Arizona 22 per cent. Statistics are given showing the cost of operation and the profits of various mines, with a résumé of the foreign and domestic copper trade.

Lead.— The value of the lead mined in 1901 was $23,280,200, this being something less than that of the preceding year. Idaho stood first in production, Colorado second, and the Mississippi valley districts third. Important developments of lead properties are now going on in southeast Missouri, and it is believed that a material increase of output will follow.

Zinc.— The value of the zinc production was $11,265,760. The quantity mined was the greatest in the history of the industry, being 25 per cent. of the world's production. More than half of this ore came from the Joplin, Mo., district. The features of the year were the removal of smelting properties to the Kansas natural-gas district and a futile attempt to consolidate the smelting interests.

Aluminum.— The Pittsburg Reduction Co. is the sole producer of aluminum in the United States. The value of the product was $1,920,000, this being half the output of the world. As an electrical conductor, aluminum continues to increase in favor. Beauxite, the ore of aluminum, was mined in Georgia, Alabama, and Arkansas. The new field at Beauxite, Ark., is one of great promise.

Quicksilver. — The production of $1,382,305 came chiefly from California, though Texas contributed a small amount. The ores being worked are very lean, and the outlook for increased production is unpromising.

Precious stones.— The production of the United States was $289,050, while the importation was $22,815,352. The jewelry trade is a very sensitive barometer of the general financial situation, and the great importation of precious stones clearly reflects the remarkable prosperity of the country.

W. H. E.